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BIRDS AND AIRCRAFT ON MIDWAY ISLANDS

1956-57 Investigations

SPECIAL SCIENTIFIC REPORT-WILDLIFE No. 38

UNITED STATES DEPARTMENT OF THE INTERIOR
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BIRDS AND AIRCRAFT ON MIDWAY ISLANDS

November 1956 - June 1957 Investigations

By

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and John W. Aldrich

Branch of Wildlife Research
Bureau of Sport Fisheries and Wildlife

SPECIAL SCIENTIFIC REPORT--WILDLIFE NO. 38

UNITED STATES
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Washington : January 1958


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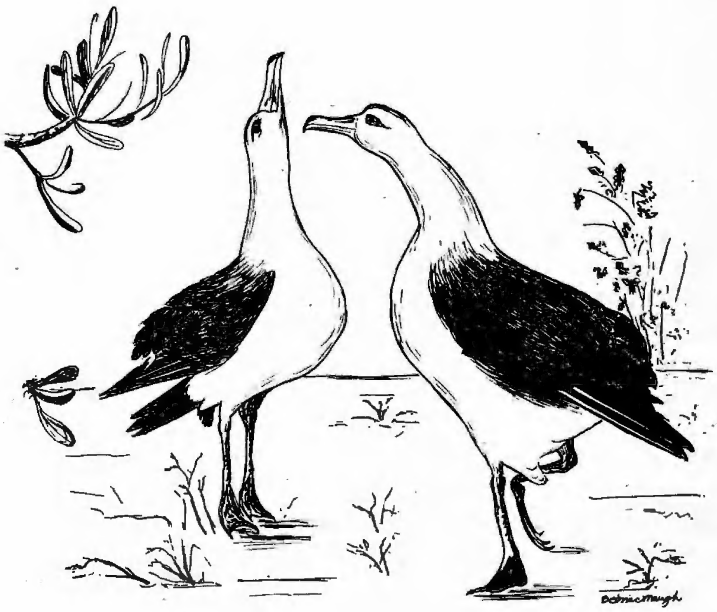


ABSTRACT

The purpose of this study is to determine the extent to which certain species of birds contribute to the hazard to aircraft at Midway; to learn more about the population dynamics and habits of these species to determine what type of control measures might be possible without endangering the species; and to test methods of control which are suggested. Most of the study has been devoted to the two species of albatrosses and the sooty terns nesting at Midway because of the current belief that these species offered the greatest danger to aircraft safety.

Albatrosses

The total albatross populations were estimated on the Midway Islands as 10,300 black-footed and 131,000 Laysan on Sand Island, and 5700 black-footed and 105,000 Laysan on Eastern Island. This compares with an estimated 116,000 black-footed and 647,000 Laysan in the entire Hawaiian chain, which comprises almost the entire breeding grounds of these two species.

Albatrosses have a highly developed homing instinct when they are engaged in nesting activities; greater when setting on eggs than after the eggs have hatched. Of 18 Laysan albatrosses removed from their nests at Midway and shipped by aircraft to distant points around the North Pacific, 14 returned from distances ranging from 1315 miles to 4120 miles.

All recorded airplane strikes of albatrosses have occurred during daylight hours; these birds are rarely in flight over Midway at night.

The most accurate information on the frequency of strikes is from control tower operators' observations from April 8 to May 31, 1957, in which period 29 albatrosses were struck during 25 out of a total of 388 landings and takeoffs; about 5 percent of operations resulting in strikes. Black-footed albatrosses contribute only about 1 percent of the total strikes.

Since Midway has been used as an airbase there are no records of human lives being lost or of aircraft having crashed because of bird strikes.

Damage from bird strikes to 7 planes was reported between November 20, 1956 and May 31, 1957. This damage was incurred during 1638 landings and takeoffs, about 99 of which resulted in bird strikes. Therefore damage to planes occurred in 0.4 percent of landings and takeoffs.

Observations of color-dyed albatrosses soaring over the runways showed these to be made up of about one-half nesting and one-half unemployed birds. Since population estimates show a ratio of 5 nesting birds for each unemployed individual, it follows that an unemployed bird is five times as great a hazard as one that is nesting.

Approximately two-thirds of the albatrosses over the runways were determined by their color markings to be from areas within 750 feet of the runways. Nesting birds from the residential area make up less than one-half of 1 percent of the nesting birds over the runways, while unemployed birds from the residential area comprised 5 percent of the unemployed population over the runways. Only 1 marked bird (unemployed) from Eastern Island has been recorded over Sand Island runways.

Nest and egg destruction at any stage of incubation shifts breeding birds to unemployed status with highly significant increase in occurrence over the runways. These birds remain on the island for many weeks in unemployed status. Parents which have lost their chicks remain in the area as unemployed birds for some time, but not as long as those which have lost their eggs.

Sterilization of eggs will cause adults to continue setting several weeks after normal hatching date.

Many young albatrosses can survive (at least until near fledging time) after the loss of one parent. Loss of both parents will normally, but not always, result in the death of their chicks.

Destruction of all birds and eggs prior to completion of the laying season results in immediate occupation of the area by other nesting birds. Destruction of all birds and eggs after laying season is complete will eliminate nesting in the area but there will be an influx of unemployed birds.

Present indications are that substantial reduction of the hazard to aircraft by killing birds would require the elimination of all nesting and unemployed Laysan albatrosses from an area extending at least 750 feet each way from the center of operational runways; that this program would have to be continued for an unknown number of years to eliminate influx of birds from all sources, including the several generations of subadult birds raised in the area which are at sea when the program is begun, and which will eventually return to nest. Evidence indicates that the black-footed albatross is such an insignificant contributor to the present hazard to aircraft that this species may be spared in any killing operation.

Areas where wind currents are deflected upwards by unevenness of land surface are used much more by soaring birds than flat areas. Under certain wind conditions the number of birds over the area with the highest trees and dunes is 165 times as great as over a level area. This suggests that leveling of the land in the vicinity of runways would be a good method of controlling the hazard to aircraft presented by soaring birds.

Sooty Terns

Observations were made of sooty terns on the nesting areas and over the runways on Sand Island and of the frequent strikes of this species by aircraft. There were three distinct colonies of this species, including about 150,000 birds, on Sand Island occupying a total area of 420,000 square feet.

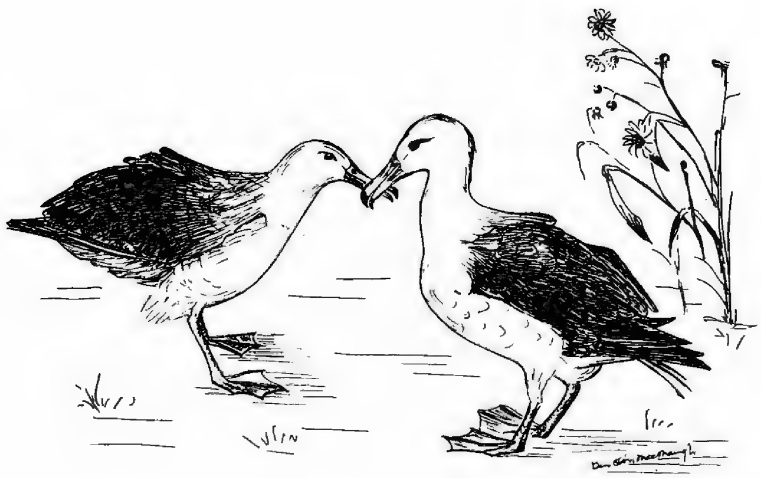
Harassment experiments were conducted using burning oil smoke, 12-gauge shotgun fire, and aircraft float lights to keep the birds off the ground when they were first arriving to start nesting activities. By these devices it was possible to keep the terns off the ground sufficiently to prevent them from making nests on ancestral sites but the program was unsuccessful in driving them from the island and preventing them from moving to other parts of the same island to nest. In view of the vast numbers of sooty terns on Sand Island, and the considerable amount of manpower and material expended with negative results it appears impractical to attempt to eliminate this species by this type of program.

Wire mesh spread over the nesting area and raised slightly above the ground keeps sooty terns from landing, but the mechanics of keeping this above the ground and the cost of the material makes this method of control impractical.

Black-topping the surface of the ground for water catchment was found to repel birds from areas where they had formerly nested. Where black-topping is feasible in sooty tern nesting areas next to runways it may effect some control of the bird problem.

Experiments with killing sooty terns with the contact poison TEPP were unsuccessful because of danger to the human population if concentrations were increased sufficiently to kill birds.

During the period of observations there was an average of 1.15 sooty terns killed per takeoff or landing without damage resulting to a single plane.



INTRODUCTION

Midway is an Atoll in the middle of the North Pacific Ocean. It is in the western part of the Hawaiian chain or Leeward Islands. A coral reef surrounds two small islands of coral rock and sand. Sand Island, the larger of these, 948 acres in extent, is the site of a U. S. Naval Air Base and has a small settlement in the northeastern corner. Eastern Island with 334 acres is largely uninhabited by humans. The runways on Eastern Island, used during World War II, are no longer used except in case of emergency. Both islands have large nesting sea bird populations of several species. These birds while in flight over the runways of Sand Island are frequently hit by aircraft and are considered to be a serious hazard to planes and human life. The currently expanding facilities at Midway for handling an expected great increase in air traffic, particularly in jets and specialized types of aircraft, make it imperative to find methods of reducing the hazard to planes caused by collisions with birds. At the request of the Bureau of Aeronautics, Department of the Navy, the U. S. Fish and Wildlife Service is investigating the problem.

Preliminary studies by Du Mont and Neff* indicated that the Laysan albatross, Diomedea immutabilis, and black-footed albatross, Diomedea nigripes, were the chief contributors to the hazard to aircraft. Their studies indicated further that ordinary wildlife repellents and scaring devices had little chance of success in deterring albatrosses either from nesting on their ancestral sites or from flying in dangerous areas over the runways. Therefore plans for the current study were to go more deeply into the investigation of the population dynamics and habits of the albatrosses; also to include study of the other species such as sooty terns, Sterna fuscata, which are considered a potential hazard to jets and more specialized types of aircraft in the future.

Previous experience indicated that no measures short of eliminating part of the bird population would effect the required safety to aircraft. Therefore good wildlife conservation principles required finding out what part of the bird population is involved in the hazard and what destruction of this segment would mean in terms of the total world population of the species. Thus plans called for determining the total populations first, the segment of the population involved in the hazard second, and measures for controlling this segment third. The plans for studies of control measures envision a thorough investigation of the habits, life cycles, and population dynamics of the birds to be able intelligently to approach the problem of keeping them out of the air over the runways; to find a method which would be permanent and yet as sparing as possible of birdlife.

The investigating team of biologists, including Aldrich, Robbins, and Rice arrived on Midway on November 17, 1956. Aldrich and

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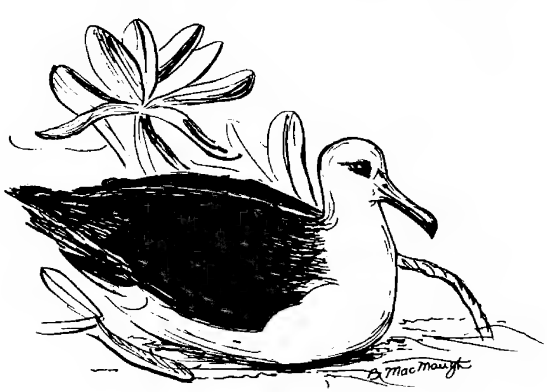
* Du Mont, Philip A., and Johnson A. Neff
1955 Report on Midway Islands albatross study.
In Bureau of Sport Fisheries and Wildlife
Washington, D. C.

Robbins left for other duties on December 12. Kenyon arrived at Midway on December 29, 1956, and continued the investigation with Rice. Kenyon left Midway for other duties on June 26, 1957. Rice remained on Midway to continue field studies. Plans call for additional biologists to join him.

ACKNOWLEDGMENTS

Cooperation extended to the biologists conducting this investigation by personnel of the U. S. Naval Station, Midway, has been and continues to be excellent. Captain E. T. Hughes, USN, Commanding Officer of the Midway Naval Station, placed the facilities of his Command at our disposal in every way possible. Men and equipment were furnished when needed. The biologists were taken on 6 flights over other Leeward Hawaiian Islands. Navy photographers took and furnished several series of photographs of these islands for albatross population studies. Every effort was extended by pilots and photographers to produce the best possible results. The pilots included: Capt. E. T. Hughes, Comdr. C. C. Shmuck, Lt. Comdr. G. M. Watson, Lt. F. L. Moody, Lt. D. H. Picht, Lt. (jg.) D. L. Slaughter, A. Vogt, ADC(AP), and B. C. Massey, ADC(AP). Lt. Comdr. J. F. Reilly was in command of a ship that took the biologists to Kure Atoll on June 5. His full cooperation made the trip both profitable and enjoyable. Many other officers and enlisted men contributed their time and cooperation to our program. C.W.O. Jones, and C.W.O. Rundle extended generous cooperation to us on Eastern Island. Patrol Squadrons VP-6, VP-46, and VP-50 cooperated by transporting albatrosses to distant points, liberating them, and sending us release information. Mr. Johnson Neff, Biologist, U. S. Fish and Wildlife Service, Denver, Colorado, gave valuable advice and information through correspondence. We especially wish to mention the indispensable cooperation extended by our liaison officer, Lt. D. H. Picht. No better officer could have been appointed to this position. Many hours of his time after regular working hours were given freely and with good humor to help us with our projects. Without his interest, energy, and unfailingly intelligent assistance much of our work could not have been accomplished. Capt. O. M. Trier, U. S. Army Chemical Corps, gave us valuable information and assistance in an experiment involving the use of the lethal contact poison TEPP on sooty terns.



PART I. ALBATROSS STUDIES

Albatross Populations in the North Pacific Ocean

In the planning stages of this study it was realized that the nature and extent of control measures recommended for albatrosses should depend to a large extent on the part of the total world population comprised by the Midway group. For this reason efforts were made, as soon as possible, not only to determine the populations of these birds on each of the two islands at Midway, but also the other islands where they breed.

During late November and early December experimental sample counts were made at Midway. Between December 21, 1956 and June 5, 1957, studies were conducted to obtain estimates of the 1956-57 breeding populations of Laysan and black-footed albatrosses on all the Leeward Islands. Kure Atoll (Green Island) and the Midway Islands were traversed on foot and sample or nearly complete ground counts made. Through Navy cooperation aerial photographs were taken of all islands except French Frigate Shoal, Necker, Nihoa, and Gardner Pinnacles. Estimates of populations were based on both the ground counts and photographic counts. The figures obtained (Table 1) must be considered as approximations which indicate the general order of magnitude of the various population units, with the exception of several careful ground counts as noted.

Methods

Three methods of obtaining albatross population estimates were employed: (1) Random-sample plot counts, (2) extensive ground counts, (3) counts on aerial photographs.

(1) Random-sample plot counts: The total populations of both species on the Midway Islands were estimated from actual counts of all albatrosses in randomly distributed 1/5-acre plots. Randomization was achieved by numbering the intersection points of a grid overlaying the map and drawing a predetermined number of these intersection numbers from a hat. For Sand Island with 948 acres, 48 numbers were drawn, and for Eastern Island, with 334 acres, 28 plots were so selected. Populations were then estimated for the two islands on the basis of these random-sample plots.

The results of this method show considerable promise for obtaining acceptable population estimates of the Laysan albatross since its nesting pairs are distributed relatively uniformly over extensive areas. However, black-footed albatrosses nest in restricted colonies which are, for the most part, concentrated in limited areas. This prevents the successful use of sample-area counts as conducted on Midway without stratification of populations. These conclusions were reached after comparing figures with careful and extensive ground counts on the Midway Islands.

(2) Extensive ground counts were obtained by enumerating Laysan and black-footed albatross nests directly. (Figures 1, 2, and 3). Each setting Laysan albatross was marked with a spot of red dye on its white breast. For this purpose a bottle having a hole in its cap and a cotton wick was attached to a 3-foot stick, so that as the breast feathers were touched a spot about an inch in diameter was left. An 8-ounce bottle held enough to mark 1000 to 1500 birds. Where nesting populations are concentrated in limited areas marking of individual birds was necessary to avoid confusion and recounting. Deserted eggs also were counted. Each nesting pair was recorded on a Veeder-Root hand tally. Black-footed albatross nests were marked by making a scratch mark in the sand at the edge of the nests. Dye was not discernable on their dark feathers.

(3) Aerial photographs of all of the islands were taken by a Navy photographer with a handheld F-56 Fairchild aerial camera, making 7 x 7 inch negatives, from the side hatch of one of the sea-air rescue planes based at Midway Naval Station. All photographs were oblique. An attempt was made to obtain over-lapping exposures. The plane flew at 200 to 500 feet during photographic runs and at 120 to 130 knots ground speed.

Each series of photographs was sorted and overlapping areas marked with ink lines. Using a magnifying glass each albatross was marked with the point of a pin as it was counted. On areas where counts were not possible because of lack of clarity and overlap, estimates were made by comparing the observed general density of birds on an area basis with areas where quite reliable counts were possible.

Results

Based on the best information available the numbers of albatrosses on each surveyed island have been estimated and appear in Table 1. It is probable that these estimates tend to be low since it is almost certain many non-breeding birds, mostly subadults, remain at sea and thus were not counted in our observations. Also a few other breeding colonies of relatively small size are known to exist. Based on the studies of 1956-1957 we believe it is safe to say that the total individuals of the two species of albatrosses under study living today in the North Pacific Ocean is about 800,000 and not more than 1,000,000.

Table 1. Summary of North Pacific Albatross Populations

Area	Black-footed Albatross	Laysan Albatross	Total both species
Kure (Green Island)	160	700	860
Sand Island (Midway Atoll)	10,300	131,000	141,300
Eastern " " "	5,700	105,000	110,700
Pearl and Hermes Reef	17,000	42,000	59,000
Lisianski Island	6,500	68,000	74,500
Laysan Island	75,000	300,000	375,000
French Frigate Shoal	2,000	1,000	3,000
Totals of estimates	116,663	647,000	763,660

Population Dynamics

Basically important to any study of wildlife control is a thorough understanding of the population dynamics of the species involved. In the current investigations at Midway it is particularly important to know details of the comings and goings of various parts of the population, their rate of mortality, and habits of the various age groups.

Recognition of Individuals

In many phases of the study of population dynamics it is essential to have some method of keeping track of individuals. This is commonly done by the use of numbered metal legbands. Fortunately marking of this sort has been conducted from time to time in the past on the albatross population. Albatrosses were first banded at Midway Atoll in 1937. Until the commencement of the present study, a total of 2334 Laysan albatrosses and 1800 black-footed albatrosses had been banded. Much valuable information has been gained from these banded birds. A summary of this work is being prepared by Johnson A. Neff, and will be published separately. In the present project numbered bands were used to mark birds on study plots where individual recognition of certain birds was necessary. Also as part of a long term study of the population dynamics of albatrosses, a large number of young birds of both species were banded on Eastern Island (Figure 4). They were marked with both standard Fish and Wildlife Service aluminum numbered bands and colored plastic bands. The aluminum bands were U. S. Fish and Wildlife Service bands. All plastic bands placed on young birds this year were red. Information sought by these bandings including mortality rate, where Midway-raised albatrosses go to breed, and age at which they first breed, may not be obtainable for several years.

Homing

A frequently suggested method of solving the problem of albatross hazard to aircraft at Midway was to remove the birds to other islands where they would not be a nuisance. Although knowledge of bird behavior in general gave little encouragement for the success of such a procedure it had to be definitely eliminated experimentally. With the cooperation of Navy Squadrons VP-6, VP-46 and VP-50 stopping at Midway while on trans-Pacific flights, 18 Laysan albatrosses were transported to distant points around the North Pacific, where they were released (Figure 5). Fourteen of these birds returned to their nests on Midway. The points where the birds were released, the number that returned, and the elapsed time en route, are summarized in Table 2, and are described in greater detail elsewhere (Kenyon and Rice, In Press, Condor).

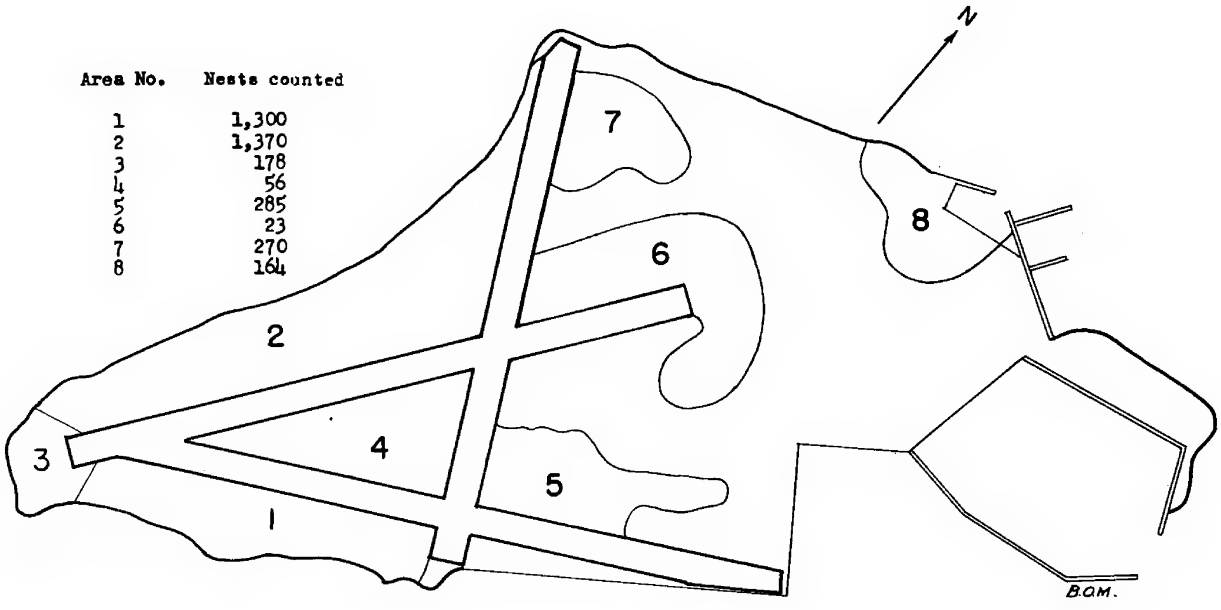


Figure 1. Black-footed albatross nest counts on Sand Island, Midway. Counts completed February 26, 1957.

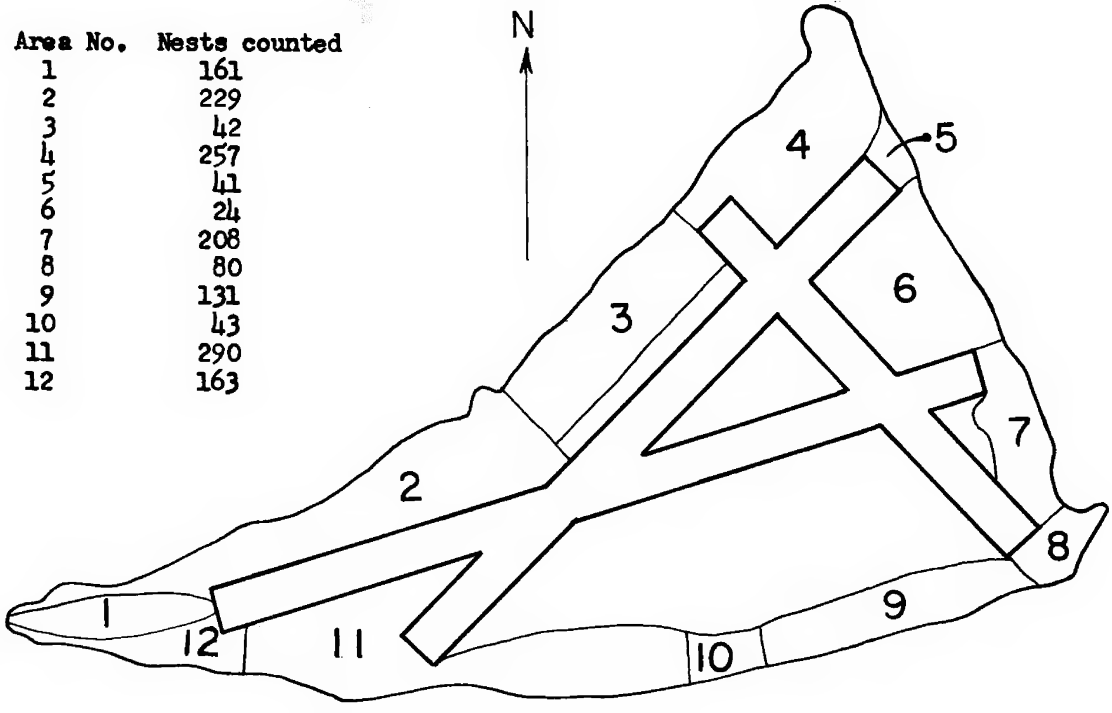


Figure 2. Black-footed albatross nest counts on Eastern Island, Midway. Counts completed February 27, 1957.

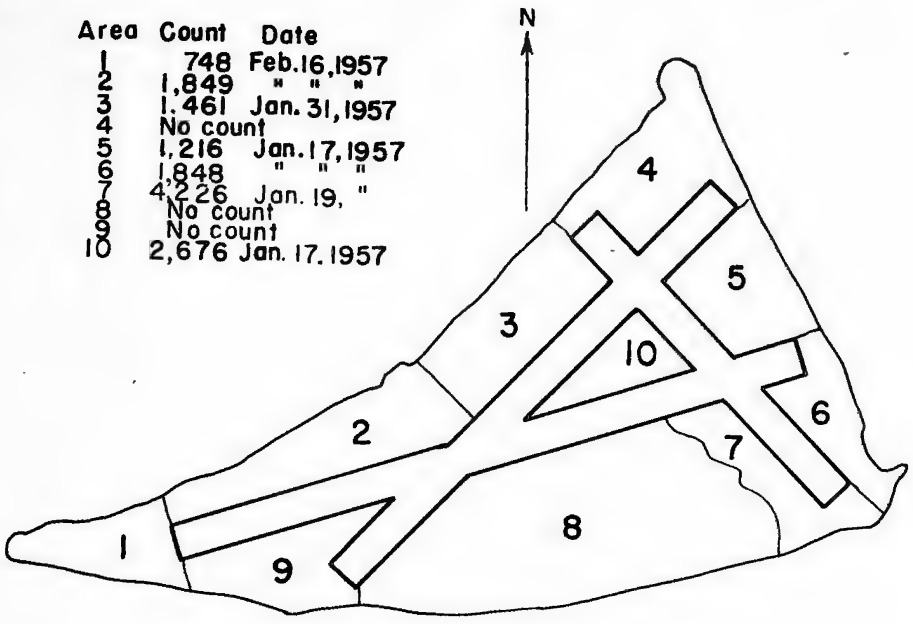


Figure 3. Laysan albatross nest counts on Eastern Island, Midway.

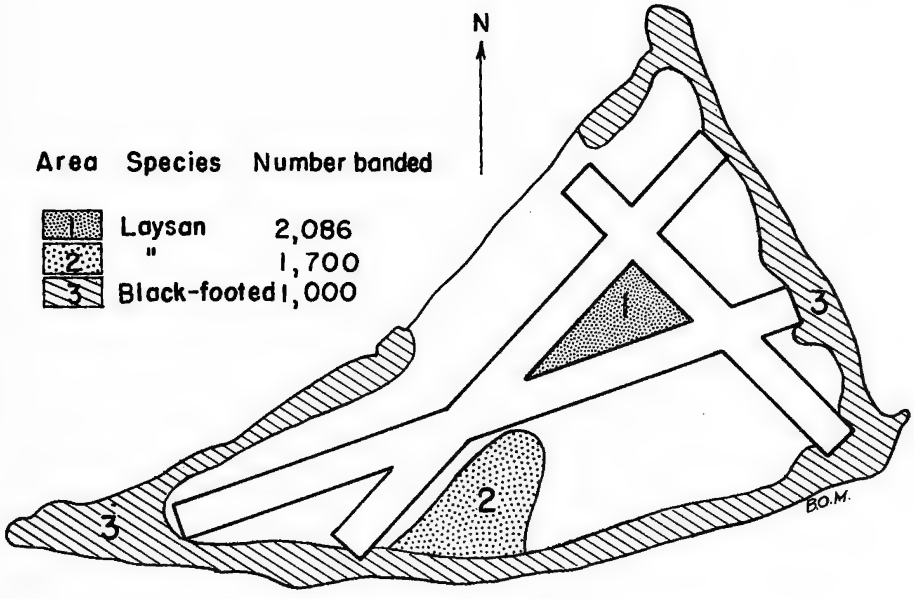


Figure 4. Localities of banding of albatross chicks on Eastern Island, Midway, May 27 to June 4, 1957.

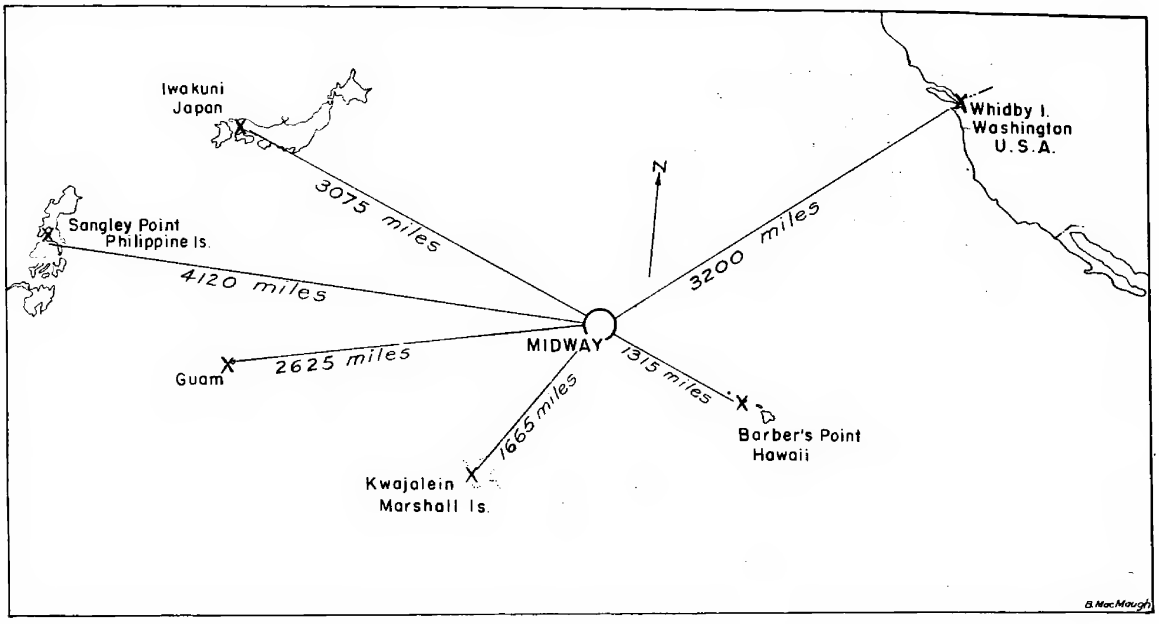


Figure 5. Localities and distances from which transported Laysan albatrosses returned to nesting places on Midway.

Table 2. Return to Midway of Nesting Laysan Albatross from Points Where Transported

Locality Released	No. Released	No. Returned	Distance (Statute Miles)	Days en Route (for fastest bird)
Kwajalein	5	5	1665	8
Guam	1	1	2625	20
Sangley Point, Philippines	1	1	4120	32
Iwakuni, Japan	3	1	3075	60
Whidby Is., Wash.	4	2	3200	10
Barber's Point, Hawaii	4	4	1315	7

Unemployed Laysan Albatrosses

Unemployed birds are those without eggs or chicks. The group includes both non-breeders and those which have lost their eggs or chicks. Large numbers of unemployed birds are on and near Midway throughout the nesting season.

Color-marking experiments showed unemployed birds are more frequently seen soaring over runways than nesting birds. We know little about the unemployed segment of the population at present. However, studies are under way and will be enlarged to obtain this information.

From studies made so far it appears that the unemployed component of the population has been greatly increased by construction operations, and by general nest destruction caused by a large human population. However, even on Eastern Island, where little disturbance has occurred, there are many unemployed birds. Although definite evidence is lacking, probably a considerable number of these birds are young frequenting the nesting grounds for a season or two before breeding.

In addition to marking of unemployed birds with colored dyes for recognition over the runways, a continuous study on a specific plot was undertaken.

In a small area near the bachelor officers' quarters, 68 unemployed birds were numbered on their breasts with Krylon spray enamel. Their occurrence within 200 yards of the marking area was recorded daily (Figure 6).

The total "bird days" involved in this study was 2516. The total "bird days" spent ashore by marked birds was 435, or an average of 17.2 percent. It can be seen from Figure 6 that the number of days spent ashore in or near the marking area varied considerably among individuals during this period. The least constant were naturally the last to be marked. The longest period a bird was seen on shore was 12 days. Several times numbered birds were seen taking off from the beach, and then were seen again in their favorite area the following day. Apparently the night and early morning hours were spent at sea, feeding. However, many unemployed birds spend two or more days ashore without leaving to feed.

In addition to the dye-marked unemployed birds seen flying over runways, marked birds have been seen on the ground at varying distances from the places of marking. (See Figure 7) Time did not permit a systematic search of remote parts of the island for marked birds. However, all those observed were recorded. Such wandering might indicate that these individuals are young birds exploring new areas prior to establishing a home territory. It is apparent, however, that unemployed birds regularly frequent favorite and rather limited areas. It would be of value to know if these are near the sites where they were hatched. These observations indicate that unemployed Laysan albatrosses remain associated with a definite area fairly constantly considering that periods of absence while feeding at sea would be expected.

Considerable more study will be necessary in order to answer the following questions about unemployed birds which are important to the airplane hazard problem: (1) What is the proportion of unemployed to nesting birds under normal conditions? (2) In what proportion are the various age classes represented? (3) How many seasons do the young birds visit the islands before nesting? (4) For how long a period do they return intermittently to land during the breeding season?

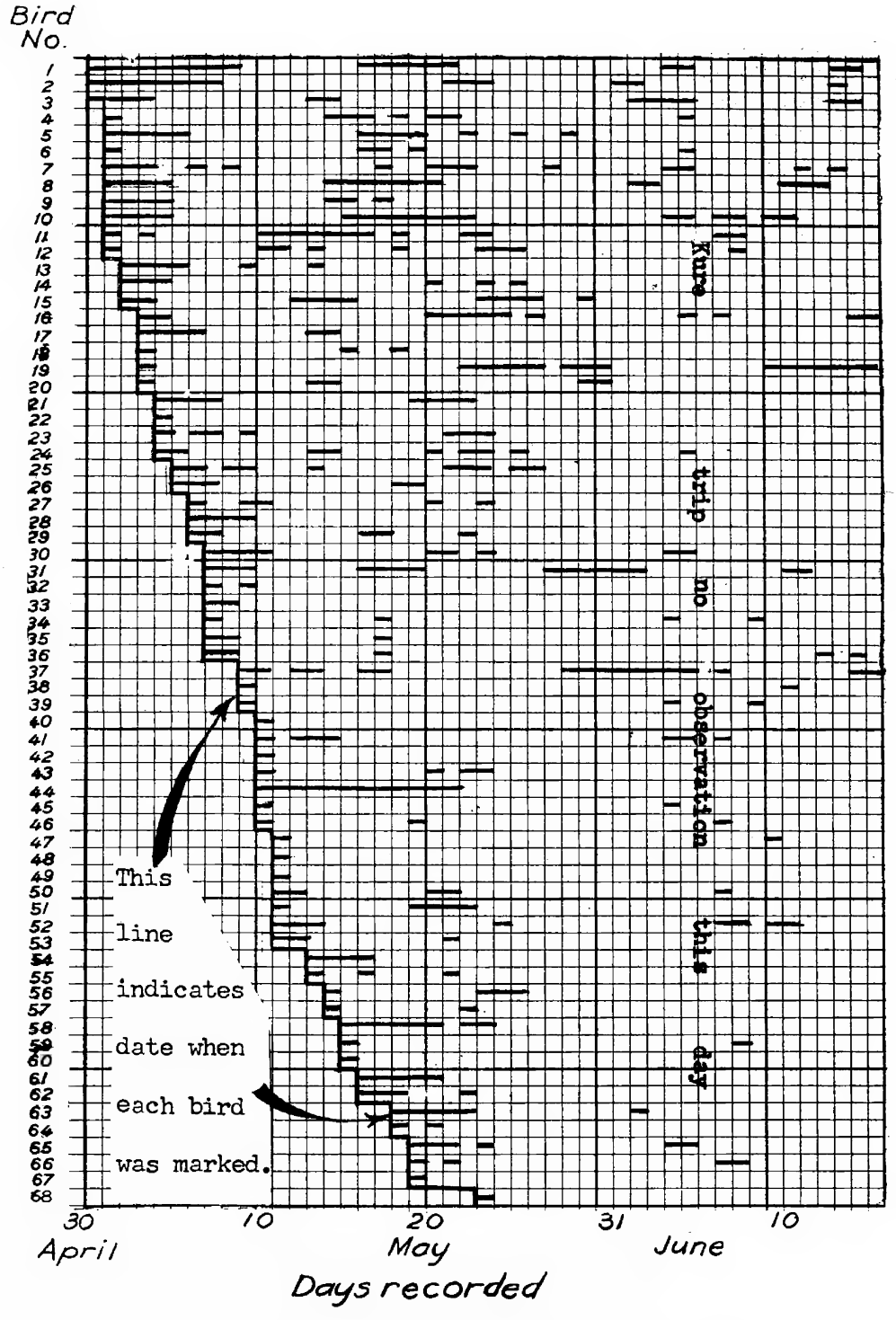


Figure 6. Days on which each of 68 marked unemployed Laysan albatrosses was observed on shore in or near--within 200 yards of--the place where marked.

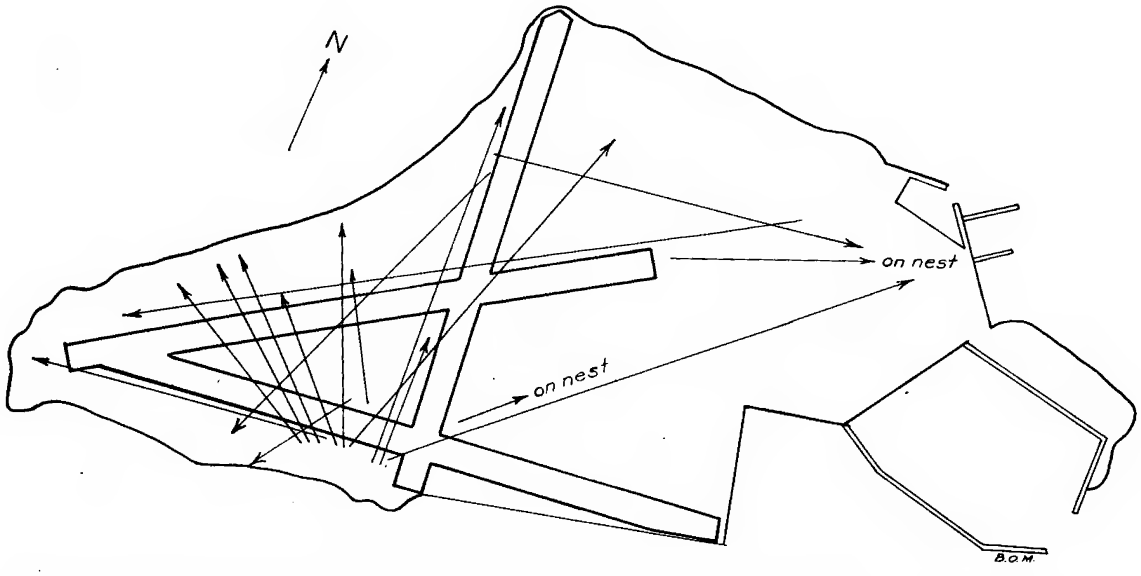


Figure 7. Movements of marked unemployed Laysan albatrosses on Sand Island. A total of 3,218 Laysan albatrosses, presumed to be unemployed, were marked, January through March 7, 1957. Two were later found on nests, as noted.

Daily Rhythm in Population

Plots were set up to determine if there is a daily rhythm in numbers of birds present on the ground and in the air. Three plots were marked off on runways for aerial counts and 6 in nesting areas for ground counts for this study. The purposes were to determine to what extent hazard to aircraft varied from hour to hour, day and night, and also to determine at what time of day populations might be most nearly static so population studies could be conducted during this optimum period. Hourly counts were made on the plots throughout the night of November 20 and the day of November 23 (a 24-hour period). The night counts showed a maximum population on the ground, with very little hourly variation. Figure 8 shows the results of the ground counts during the daylight hours from 7 a.m. to 6 p.m. A rapid decline occurs at dawn, with a minimum at 8 a.m., followed by a gradual rise until the maximum is reached again the following night. Figure 9 shows the curve for birds in the air over the runways to be the reverse of those on the ground, with a maximum peak at 8 a.m. This definitely suggests an inverse relationship between the two groups during this period in the early part of the breeding cycle. It should be noted that the ground counts showed a greater fluctuation and an earlier return to maximum populations in the afternoon on the part of the black-footed albatross which was already advanced in egg laying while the Laysan albatross had hardly begun to lay. The population of Laysan albatrosses on the ground plots did not vary more than 4.5 percent between 8 and 12 a.m. Similar counts of all birds on the ground were made in an area around the

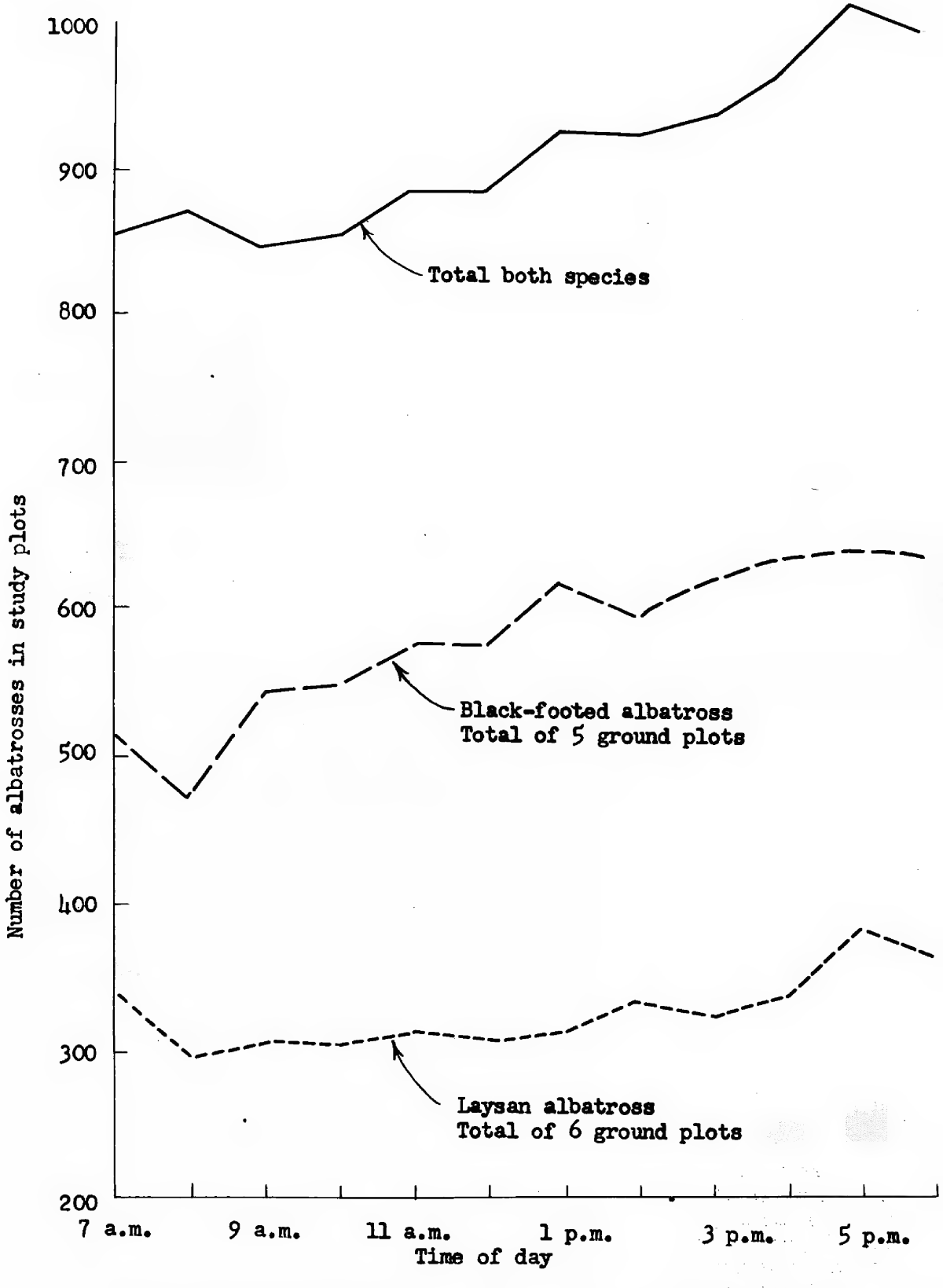


Figure 8. Ground counts of albatrosses by species. (Hourly population changes in nesting plots, November 23, 1956.)

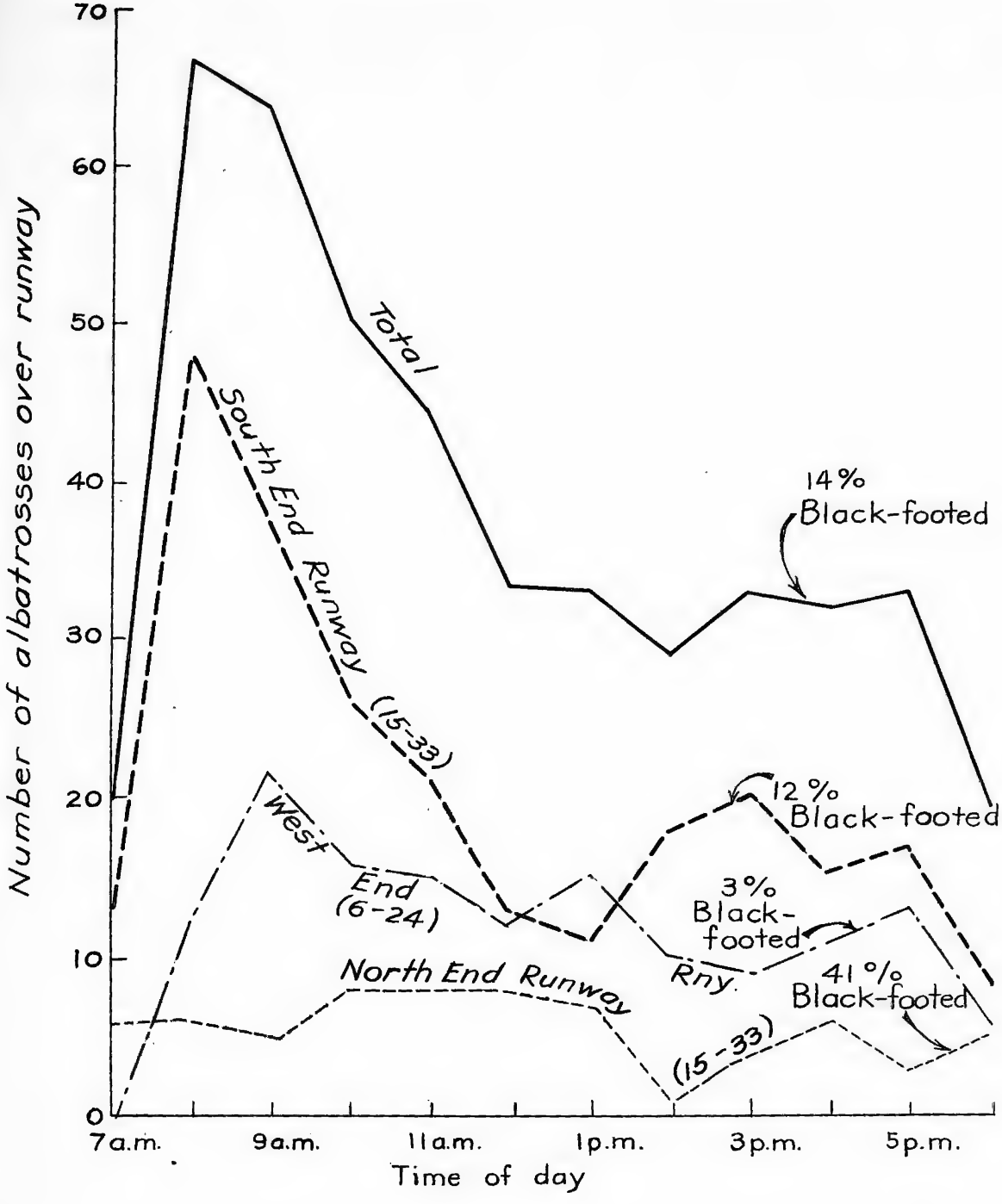


Figure 9. Runway counts of albatrosses. (Total albatrosses in air over runways, November 23, 1956.)

married officers' quarters in May and June. These showed a similar fluctuation in abundance throughout the day to those found in November.

Seasonal Fluctuations

It was our general observation that the total number of birds on shore varied considerably over a period of time. In order to evaluate this variation in abundance, counts were made frequently throughout the day on many days in May and June, in areas near the bachelor officers' quarters and married officers' quarters. Because a noon count is the most convenient to make and falls near the usual daily peak of abundance, it was chosen as the one to illustrate day to day fluctuations in abundance. Observations shown in Figure 10 indicate that abundance of Laysan albatrosses on shore on both Sand and Eastern Islands show marked periodic variation throughout the season. The gradual seasonal decline as the nesting season approaches its close is reflected also. Exactly what influences the marked periodic fluctuation in abundance we do not yet know. However, on hot, humid days it seemed to be a general rule that fewer birds were ashore.

Albatross Mortality

Sand Island.--Because of the operation of aircraft and large amount of construction work on Sand Island, albatross mortality there is much higher than on Eastern Island. It is the duty of the sanitary crew to pick up and burn the bodies of birds killed on Sand Island (except on the runways where this duty is performed by the Station Fire Department). Because of the large numbers of birds killed, only those found on roads or in the vicinity of living quarters are collected. At our request seamen detailed to this work kept records of gooney birds picked up. Their records which include both black-footed and Laysan albatrosses as "gooneys" are shown in Table 3.

Table 3. Albatross Fatalities

Month	General Pick-up	Runway Pick-up	Total
November 1956	1011	63	1074
December 1956	349	no record	349
January 1957	523	75	598
February 1957	440	75	515
March 1957	447	60	507
April 1957	523	80	603
May 1957	477	44	521
Total	3770	397	4167

Because of the intense program of construction now in progress on Sand Island, trucks are constantly in operation. Although most drivers will stop for, or avoid, a bird that is crossing the road, it is inevitable that many are killed. Birds are killed when areas for taxiways and water catchment are cleared, or when clearing land for the construction of buildings. Under these conditions the mortality

among nestlings is considerable. Many birds are buried, or starved slowly when moved from their nest area. No counts could be made, but a conservative estimate of Laysan albatross chicks destroyed in this way would be 4000, of adults 200. Since rather detailed counts of nests of black-footed albatrosses were made early in the season, and the colonies are quite discrete, a more accurate estimate as to the number destroyed is possible. About 800 chicks and 25 adult black-footed albatrosses were destroyed by construction (Figure 11).

General observations indicate that almost daily, albatrosses, both adults and chicks, are willfully killed by people working on the island. There is no accurate means of determining how many. A station general order prohibits the unauthorized molesting or killing of "gooneys." Very few violators are apprehended however, and those caught are usually seen by chance and reported by the observer.

Albatrosses are occasionally killed by striking wires, telephone poles, and trees. Some walk into open oil and asphalt sumps. Some are buried by storm-blown sand. These sources of mortality have not been evaluated, but combined are believed to be much less destructive than those created by man.

The 4167 dead albatrosses picked up and disposed of between November 1, 1956 and May 31, 1957 represent an unknown fraction of the total killed during the period. Dead birds may be found at any time in many places and in various stages of decomposition. It is estimated that 40 percent of the total scattered dead are not picked up. The total estimate (November through May) for albatrosses killed on Sand Island by unauthorized persons and by accidents is about 7000. We estimate that about one-third of these were chicks.

Eastern Island.-- A crew of 10-15 men, one jeep, and two dogs occupied Eastern Island during our study period. Few visitors are allowed on the island.

Mortality among both adults and chicks was negligible. A few birds were killed by striking aerials and guy wires. Very few dead from unknown causes were seen about the island.

Ecological Factors Affecting Albatross Abundance

Black-footed Albatross.--This species nests primarily in colonies, especially in open sandy areas near shorelines. It does not appear to spread inland to sheltered areas to any considerable degree. It is, therefore, subjected during winter wind storms to high mortality. Incubating adults as well as young were seen buried by blowing sand. We believe that its affinity for a relatively harsh environment accounts for its relatively low populations.

Laysan Albatross.--The population of this bird on Sand Island has increased from virtually nothing in 1891 to about 59,000 nesting pairs in 1956-57. This albatross nests inland in areas relatively

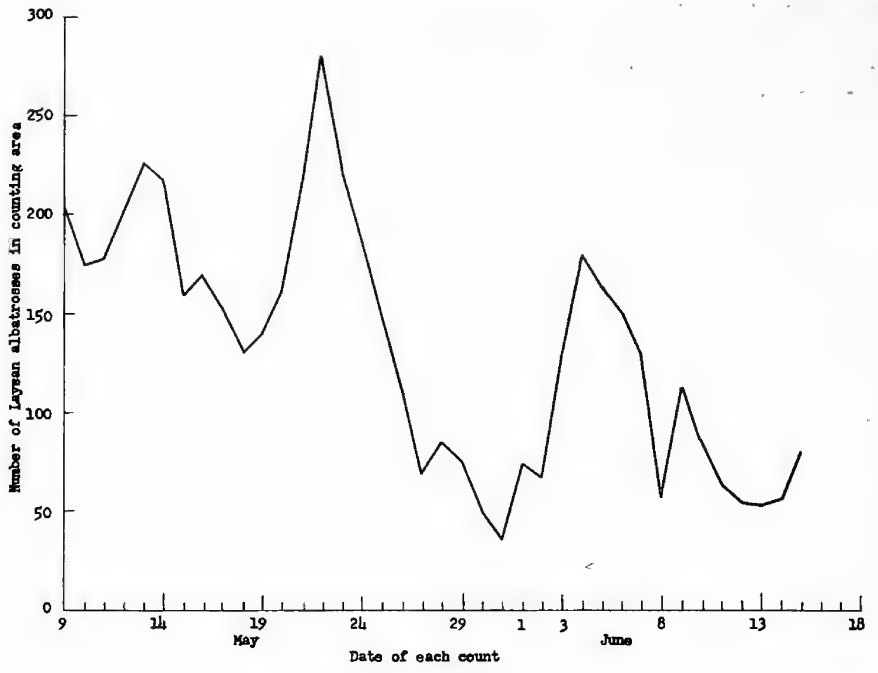


Figure 10. Variation, at 24 hour interval, of Laysan albatrosses in counting area. (Counts made at noon when abundance for the day was near its peak.)

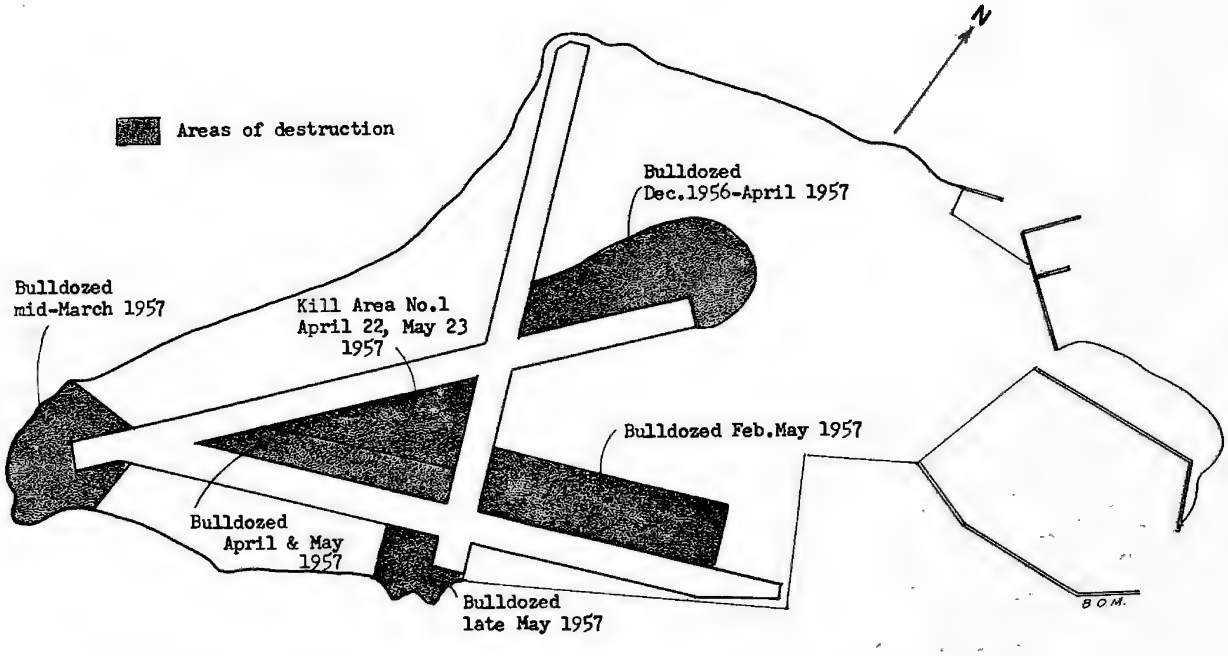


Figure 11. Areas where black-footed albatross nestlings were destroyed between February 28 and June 10, 1957.

protected by vegetation. Three factors probably contribute to this vast increase in population on Sand Island. Trees and shrubs offer protection from wind and blowing sand. Open ground interspersed with the trees and shrubs offers ideal nesting sites. Roads offer unobstructed avenues for albatross landings and takeoffs and terrestrial locomotion between sea and nest.

Because of relative protection of nests from wind and blown sand few incubating adults or nestlings in inland areas die either as a result of violent wind and rain or smothering under drifting sand. Only a few nests were established along Midway beaches. We watched while the majority of these vanished beneath the coral sand during January to March, when windstorms swept the islands for days at a time. It is apparent that survival has been greatly increased by the adaptability of this species to inland nesting sites.

Roads and openings in vegetation are important for two reasons: First, the adult albatrosses are able to reach and leave their nests during practically all weather conditions. When the wind is strong they take off and land on roadways and lawns near their nests. When wind conditions are calm, hampering takeoffs, they walk down unobstructed avenues between trees and along roads to the beaches where they run down the sloping beach with flapping wings and head out to sea. Secondly, these landscape features reduce the mortality among fledglings. The young birds have open areas in which to take their first flights, and they may walk to the beach from inland nesting sites.

Green Island, Kure Atoll, presents a situation in marked contrast to that described for Sand Island, Midway. The albatross populations on Green Island are very low. Our estimates of nesting pairs are: Black-footed albatross, 70-100; Laysan albatross, 350-400. The island is only slightly smaller than Eastern Island, Midway Atoll, where more than 40,000 pairs of Laysan albatrosses and more than 2000 pairs of black-footed albatrosses nested in 1956-57. Kure is only 56 miles west of Midway and climatic conditions are similar. A dense 100-yard wide belt of Scaevola around the central open area of the island cuts off free access to the sea for young birds raised inland. This probably accounts for the sparse population. This situation is described in detail elsewhere (Kenyon and Rice, In Press, Condor). Undoubtedly the habitat created by man on the Midway Islands through planting, keeping dense undergrowth under control, and avenues open to the beaches, is an important reason for the relatively high Laysan albatross populations on these islands.

Albatross Problem in Aircraft Operations

Time of Occurrence of Albatross Strikes

All recorded collisions of aircraft with albatross have occurred during daylight hours, between about one-half hour after sunrise and one-half hour before sunset. Albatrosses are rarely in flight over Midway during the night. Daylight aircraft operations predominated

during the present study. Ninety-seven percent of all aircraft arrivals and departures at Midway took place during daylight hours.*

Frequency of Albatross Strikes

During the period from November 20, 1956, to May 31, 1957, records of landings and takeoffs by all types of aircraft at Sand Island, Midway Atoll, were kept by the Air Route Traffic Control unit. During this period (except December), the Station Fire Department picked up all albatrosses killed on the duty runway (Runway 15-33); pickups were made every day, or every few days, depending on the number of birds killed. In Table 4 are presented the number of landings and takeoffs and the number of birds killed on the runway.

All of the dead albatrosses picked up on the runways were not killed by aircraft strikes. Many are killed by trucks. Many are killed by being thrown to the ground by the slip-stream or propeller backwash, without actually striking the plane. For this reason the number of birds picked up greatly exceeds the number actually struck by aircraft. Unfortunately data are not available on the number actually struck by aircraft during the entire period of study. Such data are available for only a relatively short period during the spring.

To determine how many of the dead albatrosses on runways were killed by aircraft, the Control Tower operators carefully observed each incoming and outgoing plane through binoculars during the period April 8 to May 31, 1957. During this period there were 388 landings and takeoffs. A total of 29 albatrosses were struck during 25 landings or takeoffs; 21 planes struck one bird, and 4 planes struck two birds. During the same period, 100 dead albatrosses were picked up from the runways.

If these figures are considered representative of the entire period of November 20, 1956 through May 21, 1957, the kill of 397 albatrosses on the runway would indicate that approximately 99 aircraft struck a total of 114 albatrosses, and 1629 aircraft struck none. On the average, one out of 16 planes landing or taking off struck a bird.

Weights of Albatrosses

Significant in appraising the hazard to aircraft presented by collisions with these birds and in designing protective features is a knowledge of their weights. Seventy-four Laysan albatrosses, killed on the study plots, were weighed (Figure 12). The lightest weighed 4.0 pounds, the heaviest, 6.5 pounds. The mean weight was 5.4 pounds. The heaviest Laysan albatross we found was a recently-returned incubating bird which weighed 8.12 pounds alive; its weight fell to 5.94 pounds before it left the nest for another period of feeding at sea.

A series of 30 black-footed albatrosses were weighed alive (Figure 12). The weights ranged from 4.75 pounds to 9.12 pounds; the mean weight was 6.8 pounds.

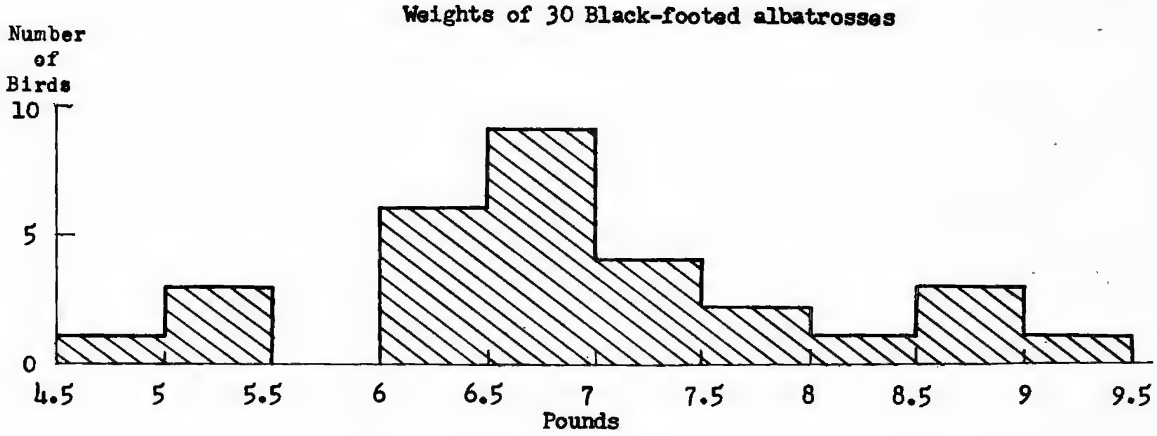
* Information furnished by the Air Operations Office, Midway Naval Station.

Table 4. Number of Landings and Takeoffs, and Number of Albatrosses Killed on Runways, Sand Island

Period	Landings + Takeoffs	Albatrosses Killed		
		Laysan	Blackfoot	Total
November 20-30	100	63	0	63
December 1-15	150			1/
" 16-31	130			1/
January 1-15	104	24	1	25
" 16-31	152	38	12	50
February 1-15	154	48	2	50
" 16-28	98	22	3	25
March 1-15	142	26	0	26
" 16-31	120	32	2	34
April 1-15	176	46	5	51
" 16-30	138	28	1	29
May 1-15	108	40	2	42
" 16-31	66	2	0	2
June 1-15	86	2	0	2
TOTALS	1728 2/	371	28	399

1/ During the period of December 1 through December 31, the Fire Chief assigned to the recording of runway bird pickups failed to keep a record because he said the kill was negligible.

2/ 3% at night.



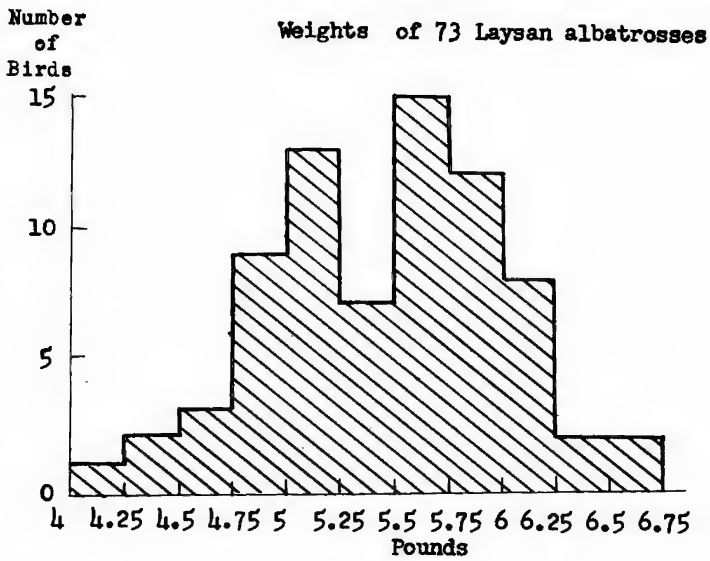


Figure 12. Weights of adult albatrosses.

Damage Resulting from Albatross Strikes

Aircraft operations began at Midway in 1935 and reached a peak during World War II. During that time there are no records of human lives having been lost owing to collisions of aircraft with birds. Likewise there are no records of planes having crashed at Midway because of bird strikes.

Between April 8 and May 31, 1957, there were 25 albatross strikes, all of which were observed by the Control Tower operator. These were incurred as follows: During landing, 10; during takeoff, 14; during taxiing, 1.

The location of these 25 strikes was as follows: Propeller, 20; engine and cowling, 5.

None of these strikes resulted in damage to the aircraft.

Between November 20, 1956 and May 31, 1957, there were 1638 landings and takeoffs, about 99 of which resulted in albatross strikes. During this period damage sustained by seven aircraft was reported to us. The details of these seven damaging strikes* are as follows:

	Date	Type Aircraft	Remarks
1)	Jan. 13	UF-1	Starboard engine cowling dented; 30 man/hours to repair.
2)	Jan. 16	UF-1	Port engine cowling dented; 30 man/hours to repair.
3)	Feb. 24	R7V	Extensive damage to starboard horizontal stabilizer; temporary repair made before departure.
4)	Mar. 5	UF-1	Starboard engine cowling dented; 30 man/hours to repair.
5)	Mar. 8	UF-1	Antenna post on port wing bent; 2 man/hours to repair.
6)	Mar. 8	UF-1	Starboard float dented; not repaired, later replaced because of other damage.
7)	Mar. 8	R6D	Port flap badly damaged; temporary repair made at Midway; flap changed at Barber's Point NAS.

The majority of albatross strikes involved Laysan albatrosses. Black-footed albatrosses constituted only 7 percent of the runway kill. No black-footed albatross strikes resulted in damage to aircraft.

* Minor damage incurred during the departure of planes from Midway was not reported back to this station.

Albatross strikes by aircraft during the period from November 20, 1956 to May 31, 1957 (Figure 13) may be summarized as follows:

	Number	Percent
Total landings plus total takeoffs	1638	100.0
Calculated number of bird strikes	99	6.1
Strikes causing damage	7	0.4
Planes lost	none	
Human lives lost	none	

Sources of Albatrosses Over the Runways

The Problem

The size and location of the segment of the total albatross population involved in collisions with aircraft will determine the type of control employed. Therefore, it was necessary to determine to what extent various segments of the nesting and non-nesting populations of albatrosses appeared in the air over the runways.

Method

Population estimates of nesting and unemployed albatrosses were made on both Sand and Eastern Islands. The estimates on Sand Island were broken down by areas (Figure 14) as follows: A strip 100 feet wide along both sides of the operational runways (symbol B); strips adjacent to the "B" strips and extending out to 750 feet from the centerline of the runways (symbol V); the residential area (symbol Y); and an intermediate area (symbol G).

About 4 or 5 percent of the breeding population in each of the subdivisions of Sand Island was dyed during the period December 6-26 with a bright DuPont aniline dye on the breast. One-eighth of one percent of the breeding population of Eastern Island was dyed in the same manner. The following dyes were used: Rhodamine B Extra Red; Malachite Green; Brilliant Milling Blue; Milling Yellow; and Violet (made by mixing red and green). The dye was dissolved in ethanol (specially denatured Ethyl Alcohol Formula 3A, furnished by the Navy). It was first applied to the birds' breasts with a paint brush, while the birds were being held. Later it was found that the incubating birds could be sprayed directly on the breast with 3-gallon decontamination sprayers. This method was much faster. The red dye had excellent lasting qualities when a strong solution was applied in quantity. The green dye faded in one to three months. The yellow and blue dyes faded very rapidly.

The exact areas in which dyeing was done and the number of birds in each sample are shown in Figure 14, together with the color designation symbols: B = blue, V = violet, G = green, Y = yellow, and R = red. The inset map in the top left corner shows the relationship between Sand Island and Eastern Island.

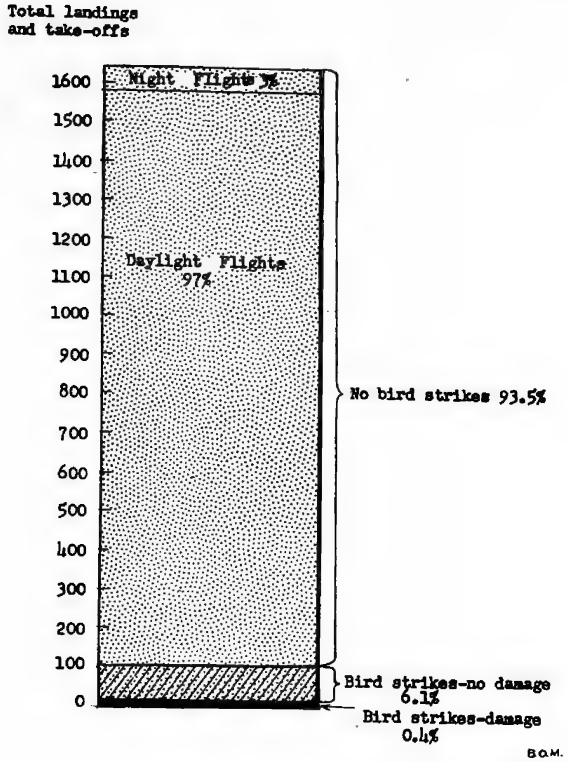


Figure 13. Aircraft operations related to bird strikes, November 20, 1956, to May 31, 1957.

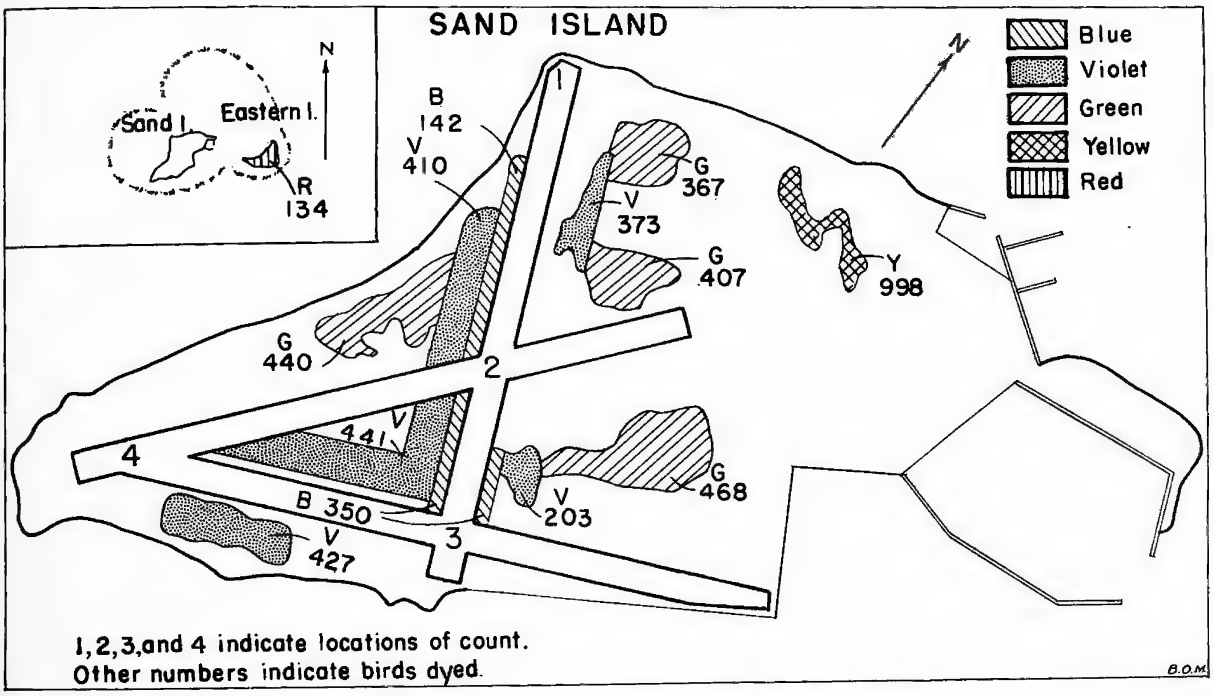


Figure 14. Areas where nesting albatrosses were dyed.

Large samples of unemployed birds were marked with Krylon enamel paint, readily distinguished from the dyed nesting individuals. The locations of painting, the numbers painted, and reference symbols for each group are shown in Figure 15. In addition to those shown on the map, 400 unemployed birds designated by the symbol "NG" were dyed in March within area "B". The Eastern Island birds were marked on March 7; the others, between January 22 and February 14.

Half-hour and one-hour counts of birds flying over the runways were made at various times of the day during the period December 27 through March 18 for nesting birds, and February 14 through March 18 for unemployed birds. Sixty-eight hours were spent in making these observations through March 18, and the counts were divided about equally among the locations shown by numbers 1, 2, 3, and 4 on the Sand Island runways (Figures 14 and 15).

Analysis

Statistical tests were conducted to test variation in percentage occurrence of the various marked birds, and correlation if any with time of the day, period of the winter, and observation location. Field observations indicated, and statistical tests confirmed that the blue dye (Brilliant Milling Blue) faded so rapidly as to be of no use for the present study. For purposes of analysis the birds in the 100-foot wide blue strips were allocated to the adjacent violet areas and considered as unmarked violet birds.

Construction operations interfered considerably with field investigations. In particular, a large area that contained violet breeding birds was bulldozed, destroying the nests and transferring an unknown number of violet birds to unemployed status. There was a highly significant increase in violet birds over the runway on and after February 21 (the day of greatest disturbance). A corresponding highly significant decrease in proportion of green birds occurred at the same time; this was probably due in part to appearance over the runways of many newly unemployed birds from the violet area, and possibly a result of other factors not immediately apparent.

In view of the drastic changes in percentage occurrence of some segments of the population from February 21 on, related in large part to habitat disturbance, only those observations prior to this date are included in the analysis in Table 5. Of 10,155 observations of Laysan albatrosses over the runways during this period, 166 or 1.6 percent were dyed breeding birds. Knowing the percentage of birds dyed in each area, an estimate of the total number of breeding birds represented in the runway counts was computed. This number, 4722, comprises nearly half of the total runway observations and indicates that breeding birds contribute about half of the birds over the runways, and unemployed birds the other half.

Table 5. Occurrence of Marked Nesting Birds Over the Runways
December 27 - February 19

	Blue	Violet	Green	Yellow	Red	Total
Number nesting	10,000	48,000	41,000	22,000	105,000	
Number marked	(492)	1,854	1,682	998	134	
Percent marked	(4.9)	3.9	4.1	4.5	0.13	
Number marked birds observed	(13)	103	62	1	0	179**
No. represented by dyed birds observed* est.	550	2,640	1,510	22	0	4,722
Range (confidence limits)	440 to 655	2,120 to 3,140	1,130 to 1,890	0 to 66		
Percent contribution to breeding bird hazard		67.5	32	0.5	0	100
Range		57-77	23 42	0-1.8		

* February 14, location 2 and February 15, location 4, omitted pending verification of number of unmarked birds seen.
** Total of both marked and unmarked birds observed was 10,155

Table 6 presents the best information available at the present time on the contribution of unemployed birds to the aircraft hazard. Unemployed birds are not evenly distributed over the two islands, but are concentrated in areas of greatest habitat disturbance. Marked samples are not representative of the whole of Sand Island, but only of the areas where marking was carried out. The proportion of marked to unmarked birds has been estimated very tentatively, as the unemployed population is far from static; repeated observations of the proportion of marked to unmarked birds on the ground will have to be made before statistical analysis can be attempted. The figures in Table 6 must be considered as tentative. Special effort will be made to obtain more data.

Although unemployed birds move around considerably, they are most frequently observed at the runway observation points closest to the area where they were originally marked. GB birds (Figure 15, Table 6), for instance, were noted two to three times as frequently at location 3 as at locations 2 or 4, and thirteen times as frequently at location 3 as at location 1. Similarly, half the observations of BN birds came from observation point closest to the area of marking. About three-quarters of the observations of BO birds were made at locations 2 and 1. Birds from the residential area (OO) were seen with greatest frequency at locations 1 and 4, indicating a tendency for these birds to cruise along the northern shoreline of the island.

Table 6. Occurrence of Marked Unemployed Birds Over the Runways February 14 to March 18 (Symbols indicate areas in Figure 15)

	GB	GS	BO	BN	OO	RH	Unmarked Area	Total
Number marked	400	100	1000	250	1000	300	0	3050
Est. percent marked in each area	7	8	18	45	17	?	--	
Number observed*	189	6	124	92	46	1	0	458
No. represented by observed birds (est.)	2700	75	690	204	270	?	1494**	5433***
Est. percent contribution to unemployed bird hazard	50	1	13	4	5		27	100

* See note previous table.
** Est. total unemployed birds less estimated number from marking areas.
*** Total birds counted over runways less number of nesting birds.

The only correlation found between time of day and appearance of any segment of the population over the runways was a statistically significant increase in unemployed birds from the residential area during the period between 11 a.m. and 3 p.m. It is possible that low wind speed in the early morning and late afternoon may be a factor restricting the flying of albatrosses from the sheltered residential area.

Conclusions

1. About half the birds over the runways are nesting birds; the other half are unemployed birds.

2. Since population estimates show a ratio of 5 nesting birds for each unemployed bird on land at a particular time, an unemployed bird is roughly five times as great a hazard as a nesting bird.

3. Approximately two-thirds of the birds over the runways (nesting and unemployed birds alike) come from within 750 feet of the runways.

4. Nesting birds from the residential area make up less than one-half of one percent of the nesting birds flying over the runways (or less than one-quarter of one percent of all the birds over the runways).

5. Unemployed birds marked in the residential area comprise roughly 5 percent of the unemployed population over the runways (or about 2.5 percent of the total population over the runways). At the

present time we do not know how closely these birds are associated with the residential area; some of them, at least, are birds from other areas that are present only occasionally within the limits of the residential area. (See Figure 7.)

6. Nest destruction shifts breeding birds into unemployed status, with a highly significant increase in occurrence over the runways.

7. Only one marked bird (unemployed) from Eastern Island has been recorded in the observations over the Sand Island runways, indicating that Eastern Island birds contribute only an insignificant amount to the hazard.

8. It must be pointed out that the above statements apply only to the specified period of observations. Different conditions may prevail at other periods of the nesting cycle.

Studies of Control Methods

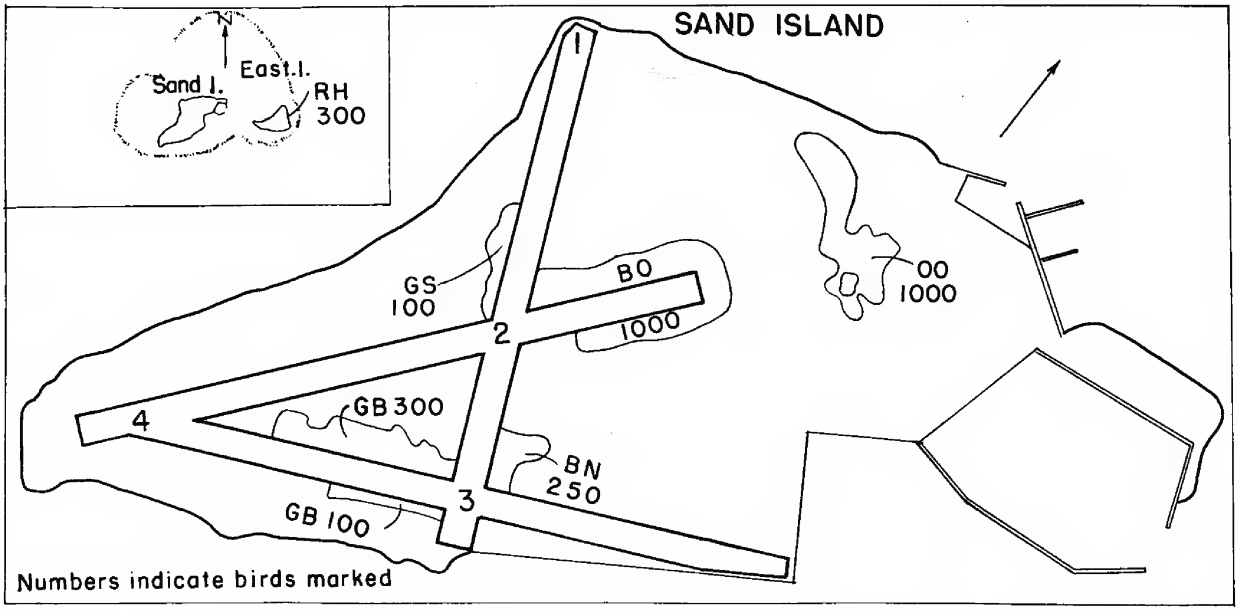
Small Scale Elimination Experiments

A series of plots was established on which the effects of elimination of certain segments of the population, at certain stages in the breeding cycle, could be measured on a quantitative basis under controlled conditions (Figure 16). The objectives were twofold: (1) To determine the results of such control methods during the present season, and (2) to determine how such control methods affect the breeding population in the following year. The results of the first phase are summarized here.

On all plots (except No. 1), all nests were marked with numbered stakes, and both birds of each pair were banded with numbered bands and given a distinctive dye mark, making them easily recognizable. (On plots No. 2 and No. 7, only the surviving member of each pair was marked.) Plots were checked every two or three days.

Effects of total destruction early in the nesting cycle (Plot No. 1).--On an area of approximately one-half acre (187 x 110 feet), all of the 67 albatrosses and all of their eggs were destroyed on December 2 (Figure 17). Following this removal there was a rapid repopulation of birds on the area. In two weeks the number of nests with eggs was 50 percent that of the pre-kill population, and the total number of birds present over 75 percent that of the pre-kill number.

On January 4, all birds and eggs in this plot were again destroyed (Figure 17). Again, there was a rapid repopulation. By the end of the month there were almost as many as had been present prior to the December kill. However, no eggs were laid on the area after the January kill.



GB-OO-BN
RH-GS-BO are symbols designating marked samples (see Table 6)

Figure 15. Areas where unemployed albatrosses were painted or dyed and those referred to in population reduction experiment.

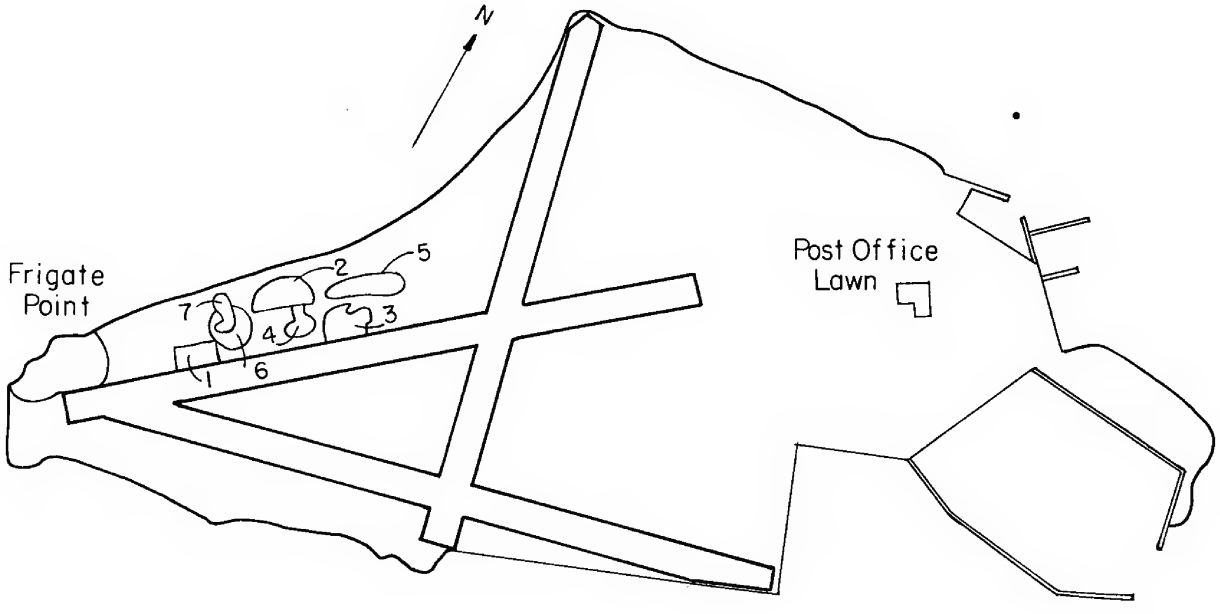


Figure 16. Small elimination experiments (plots 1 to 7) and special study area on post office lawn, Sand Island, Midway.

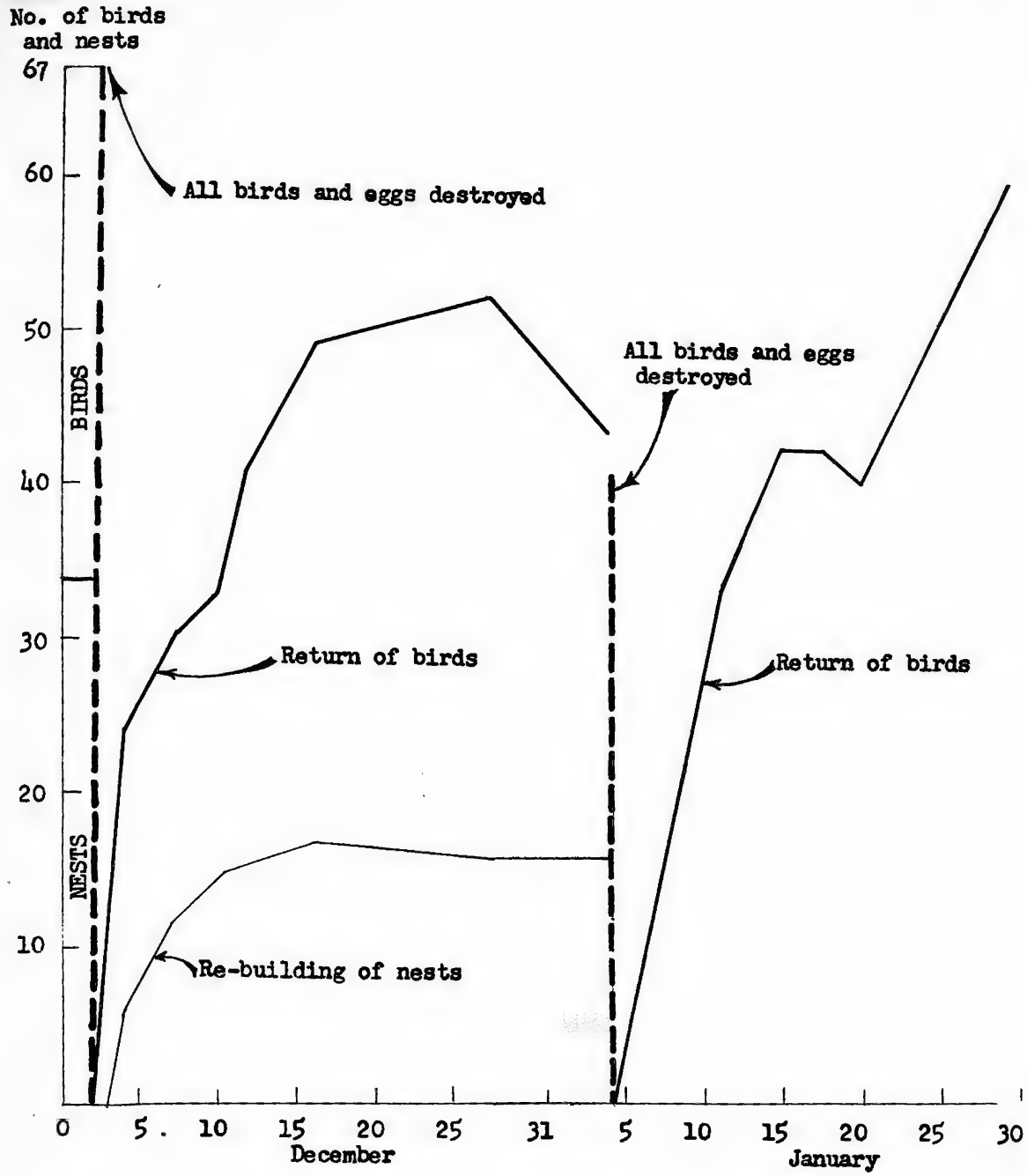


Figure 17. Effect of total extermination of Laysan albatrosses on a half acre plot.

It was concluded that destruction of all birds and eggs prior to completion of the laying season will result in immediate reinvasion of the area by other nesting birds. Destruction of all birds and eggs after the laying season is completed will eliminate nesting in the area, but an influx of unemployed birds will populate the area. The question remains, would the birds that laid eggs after the first kill have nested in the area regardless of whether or not the December 2 kill took place? Perhaps mates of birds killed remated with new arrivals after returning from the sea.

Effects of the loss of one member of each pair during incubation (Plot No. 2).--On this plot, all setting Laysan albatrosses were banded and dye-marked. Their mates were then killed when they returned to take over incubation duties. At 76 nests one member of each pair was thus eliminated. The fate of these nests is as follows:

Number of nests at which one pair-member was killed	- 76	(100%)
Number of nests at which mate continued to incubate	- 59	(79%)
Number of nests immediately deserted	- 17	(23%)
Number of nests at which additional (presumably unemployed) birds incubated	- 26	(34%)
Number of young which hatched	- 1	(1%)

Only one bird which continued to incubate did so long enough to hatch a chick, and it did so with the help of a new mate. All birds left the area immediately upon ceasing to incubate.

It was concluded that elimination of only one member of each pair during incubation will result in immediate or eventual desertion of 99 percent of the eggs. The remaining member of each pair will leave the area as soon as it ceases to incubate.

Effects of egg destruction early in incubation (Plot No. 3).--Eggs were destroyed at a total of 95 nests between November 30 and December 25. In four nests new eggs were laid. In each case the original male remained at the nest site. In one instance the male had acquired a new mate; in two instances it is not known whether it was the first or second mate which laid the second egg. In only one case did the same pair appear to lay another egg; however, this egg could have been laid in their nest by another female. Two of the four eggs successfully hatched. One male whose egg was destroyed deserted his nest and nested again nearby with a new female; this egg did not hatch. In two cases, pairs which lost their eggs adopted deserted eggs in nearby nests, and successfully hatched and raised the chicks.

Birds which lost their eggs remained in the area for several months as unemployed birds. The numbers of these birds remaining near their nest territories are shown in Figure 18. All of the birds which disappeared did not leave the island however. A thorough search of the general area of the study plot on January 30, revealed 38 marked birds from the plot; at that time only three or four could be found near their nesting territories.

It was concluded that destruction of eggs early in the incubation season results in the parents remaining on the island for many weeks as unemployed birds.

Effects of egg sterilization (Plot No. 4).--In 80 nests the eggs were sterilized by injecting them with 2 cc. of ethanol. The albatrosses continued to incubate them for several weeks after the normal hatching date, as indicated in Figure 19. The birds left the area when they finally discontinued setting.

It was concluded that sterilization of eggs will cause the birds to continue setting several weeks after the normal hatching date; they will leave the vicinity after finally deserting the eggs.

Effects of egg destruction late in incubation (Plot No. 5).--This experiment was conducted in the same manner as the one on Plot No. 3, except that the eggs were destroyed late in the incubation period. Eggs were destroyed at a total of 70 nests between January 8 and January 31. No eggs were laid in any of these nests after destruction of the original egg. The number of birds remaining near their nesting territories are shown in Figure 18.

It can be seen that the birds deserted their nesting territories more rapidly than did the birds whose eggs were destroyed early. However, as in the latter experiment, the desertion of nesting territories did not necessarily mean that the birds had left the island. On January 30, a thorough search of the general area revealed 43 marked birds from the study plot.

It was concluded that destruction of eggs late in the season results in the parents remaining on the island for several weeks as unemployed birds.

Effects of the loss of newly hatched chicks (Plot No. 6).--On this area the chicks at 63 nests were removed a few days after hatching. The length of time the parents remained in the area is shown in Figure 20. It can be seen that the parents remain in the area for some time after the loss of their chicks, but do not remain as long as birds which have lost their eggs.

It was concluded that destruction of newly hatched chicks results in the parents remaining in the area for a short time as unemployed birds.

Effects of the loss of one member of each pair after hatching (Plot No. 7).--One member each of 16 pairs of Laysan albatrosses was killed a few days after their chick hatched. Four of the young birds starved to death, three were killed accidentally, and nine survived until the end of the observation period (June), being fed by the surviving parent.

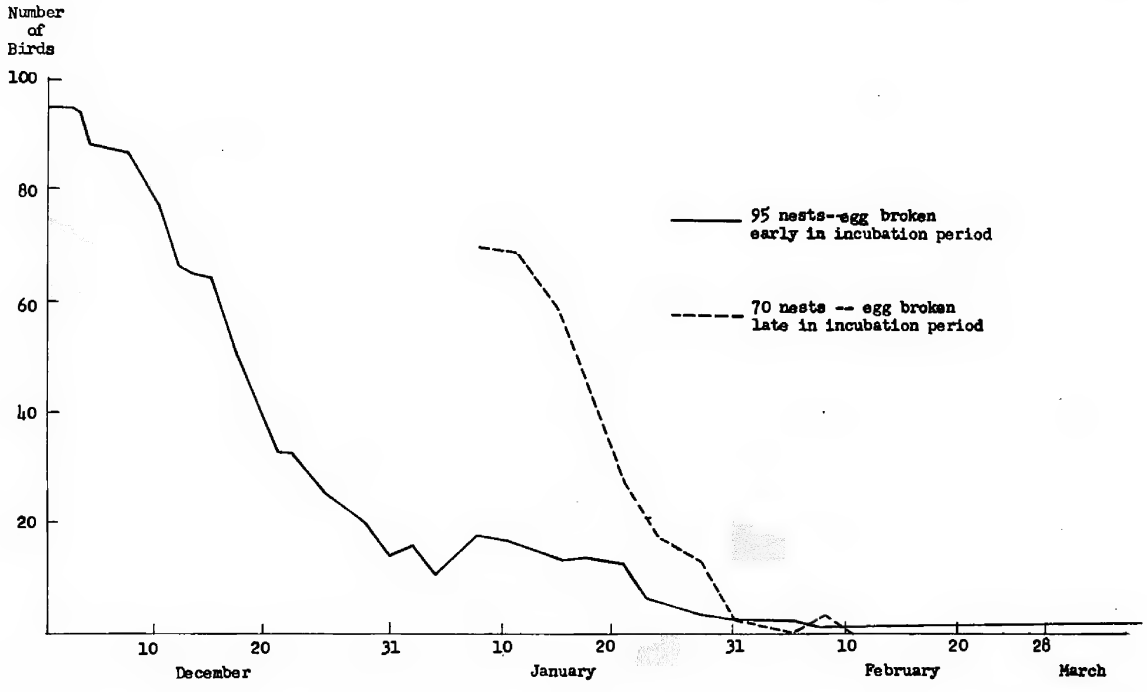


Figure 18. Number of Laysan albatrosses remaining in the vicinity of their nest sites after destruction of their eggs.

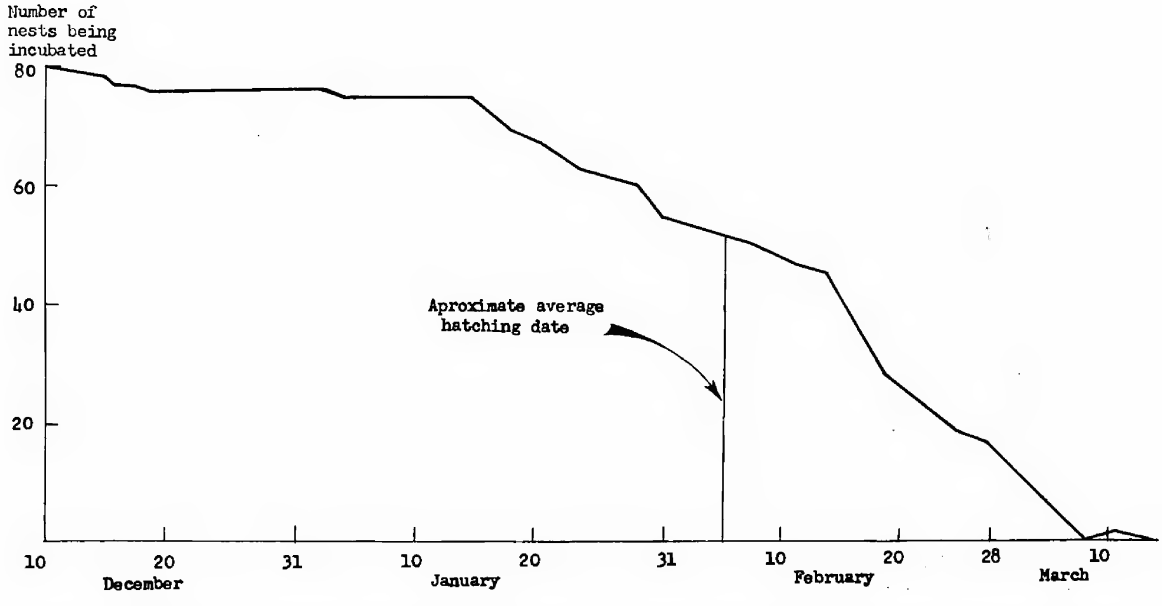


Figure 19. Length of time Laysan albatrosses continue to incubate sterile eggs.

It was concluded that many young albatrosses can survive (at least until near fledging time) after the loss of one parent.

Effects of the loss of both parents (Plot No. 8).--At seven nests both parents were killed a few days after the chick hatched. Six of the chicks soon died of starvation. One chick has survived, evidently being fed by one or more unemployed birds, perhaps individuals which had lost their own chick.

It was concluded that loss of both parents will normally, but not always, result in the death of their chick.

Large Scale Elimination Experiment

During World War II at the Marine fighter base then located on Eastern Island, Midway, an attempt was made to reduce the number of albatrosses. An officer who was on the island at the time of the killing program has kindly furnished the following recollections.

The program was conducted during late 1941. Its duration was about one week. It was conducted by 150-200 men who spent 6 or 7 hours a day killing birds. Approximately 80,000 albatrosses were estimated to have been killed. The albatross population was temporarily reduced and for a brief time the hazard to aircraft was reduced. The following season there appeared to be as many albatrosses as before. It is interesting to note that today Eastern Island has a very high population of albatrosses, about 110,000 individuals of both species combined and averaging 137 nests per acre.

In order to evaluate statistically the effects of large scale killing under controlled conditions, a population reduction program was begun on April 22, 1957, in kill area No. 1 of Sand Island (Figure 21). This 49-acre area is triangular in shape and is bounded on all sides by paved runways. It consists of Scaevola thickets, open areas, abandoned building, revetments, and is the location of the present air control tower. About one-third of the area, along the south side, had recently been cleared by bulldozers as part of the rebuilding of runway 6-24.

Procedure.--The killing was done by specially detailed men armed with short lengths of pipe or wooden clubs. The birds were killed by a blow on the back of the skull where the neck attaches. After being killed, the birds were dragged to the runways or revetments which were accessible to trucks. Here they were counted and loaded into the trucks. The first night's kill was dumped at sea; the birds from subsequent kills were buried. The first two kills were conducted at night. Subsequently they were carried out during daylight hours.

The progress of the kill is presented in Table 7.

The number of truck hours consumed was 55; of man-hours 920, during 12 killing periods. (These figures include the man-hours

involved in actually killing birds as well as the time utilized during subsequent "clean-up" runs necessitated by the large number of dead birds left scattered on the ground.)

Table 7. Kill of albatrosses in large scale experimental elimination (Kill Area No. 1)

Kill No.	Date	Adult Laysan Albatrosses		Adult Black-footed Albatrosses		Albatross Chicks		Total Birds	
		No.	Cumul.	No.	Cumul.	No.	Cumul.	No.	Cumul.
1	Apr. 22	1431	1431	64	64	847	847	2342	2342
2	Apr. 23	545	1976	16	80	88	935	756*	3098
3	Apr. 26	351	2327	15	95	192	1127	558	3656
4	Apr. 29	977	3304	2	97	60	1187	1039	4695
5	May 2	248	3552	1	98	24	1211	273	4968
6	May 9	242	3794	2	100	42	1253	286	5254
7	May 16	127	3921	0	100	59	1312	186	5440
8	May 17	190	4111	0	100	25	1337	215	5655
9	May 20	130	4241	0	100	12	1349	142	5797
10	May 21	196	4437	0	100	15	1364	211	6008
11	May 22	202	4639	0	100	7	1371	209	6217
12	May 23	49	4688	0	100	0	1371	49	6266*

* Includes 107 birds of unknown species and age (probably all Laysan albatross).

Twelve sweeps of the experimental killing area between April 22 and May 23 resulted in a kill of 4788 adult, 1371 young, and 107 albatrosses of unknown age, a total of 6266 (see Table 7).

A total number of albatrosses using the area this season was calculated to be 6216 adults and 2511 chicks, a total of 8727. These figures are based on a count of all nests in the area on January 11, and February 25, 1957.

	Laysan albatross	Black-footed albatross	Total
Total count of nests	2455	56	2511
Estimated original nests	2602	62	2664
Total breeding population	5204	124	5328
Estimated unemployed birds	867	21	888

Twelve "clean sweeps" spread over a one-month period resulted in the elimination of 77 percent of the adult albatrosses known to be using the area this season, and the chicks were virtually eliminated. The considerable difference between the number of chicks killed and the nest count in January and February resulted from mortality of nestlings during construction work along the south side of the area.

Discussion.--Two factors must be considered in evaluating the results of the population reduction program. (1) The number of years the young birds remain at sea before returning to the island is still unknown. Studies of the royal albatross in New Zealand by Richdale* show that these birds do not ordinarily return until their sixth or seventh year. On the other hand, according to Sorensen**, the light-mantled sooty albatross returns at the end of its second year. Data on our Laysan and black-footed albatrosses are fragmentary. The earliest age at which a Laysan albatross is known to have returned is 7 years, and for the black-footed, 5 years. Any killing program, to be successful, must therefore be carried on for a sufficient number of years to eliminate the several generations of birds which may be at sea when this program is begun. (2) The frequency with which adult birds return to breed is unknown. Data on the royal albatross obtained by Richdale* indicate that these birds breed in alternate years if they are successful in raising a nestling. Possibly the Laysan and black-footed do likewise. Information from returns of banded birds will eventually answer these questions.

The effect of the killing program on the number of albatrosses soaring over the runways is difficult to evaluate. The

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* Richdale, L. E. 1952. Post-egg period in albatrosses. Biological Monographs, Ortago Daily Times and Witness Newspapers Co. Ltd., Dunedin 4:1-166

** Sorensen, J. H. 1950. Light-mantled sooty albatross at Campbell Island. Cape Expedition Series 8:1-30

results are masked by: (1) The great fluctuations in abundance in different soaring areas caused by differences in wind direction; (2) a gradual decline during late May and June in the number of albatrosses at Midway (apparently this decline is a function of the advancing season); (3) fluctuations in the daily abundance of albatrosses on and over the island; (4) construction work which is continually disrupting the normal behavior of the population.

On May 22, the first "clean sweep" was made across experimental kill area No. 1. A total of 1495 adult albatrosses was killed. On the following day, runway counts at station No. 2 (Figure 21), which is adjacent to the killing area, revealed 246 soaring albatrosses per hour as compared with 96 per hour just prior to the kill. This is an increase of 156 percent in the birds soaring over the runway adjacent to the kill area.

Runway counts, although subject to the many variables listed above, did not detect any consistent difference in albatrosses soaring over the runways after the birds had been eliminated from kill area 1. It is realized that the population reduction experiment was conducted too late in the season to be most easily evaluated and was on too limited a scale to give really conclusive results.

Terrain as a Factor Affecting Albatross Abundance Over Runways

The effects of topography and wind direction on the abundance of albatrosses soaring over the runways were determined by counting the numbers of birds passing through certain index sectors. Each index sector was a vertical triangle at right angles to the long axis of the runway, delimited by the spot on which the observer stood, a point on the ground across the runway, and the summit of a selected tree or other eminence across the runway. In level areas, where no objects were present to measure height, the observer determined the angle of elevation of individual birds by extending his fingers at arms length and judging height on a predetermined scale, so that the counts at each sector station are comparable. Since the apex of the triangle was on the side opposite the observer, a much larger amount of flying space was included on that side of the runway. Therefore, each count primarily reflects abundance on the side of the runway opposite the observer. Individual counts lasted ten minutes. This interval was established after a number of trials which indicated that under a given set of conditions longer counts were a waste of time. Following is a description of the six index counting stations at which counts were repeatedly made (Figure 21):

Station 1. North end of runway 15-33. Observer on west side. Dunes and tall trees along east side. The trees here were taller than at any other point, creating the most favorable updrafts for soaring.

Station 2. On runway 15-33 immediately south of taxiway intersection. Observer on west side. Area level, except for buildings on east side. The buildings here create small updrafts which are not so great as those at areas 1, 3 and 4.

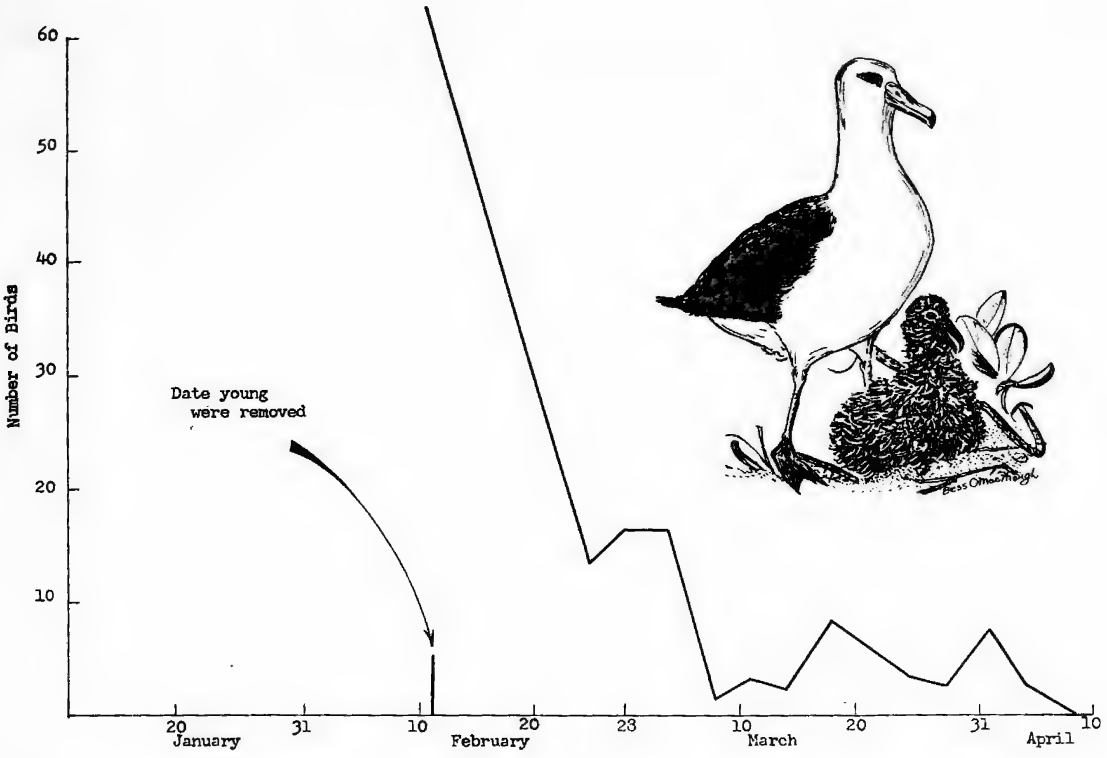


Figure 20. Number of Laysan albatrosses remaining in the vicinity of their nest sites after loss of newly hatched young.

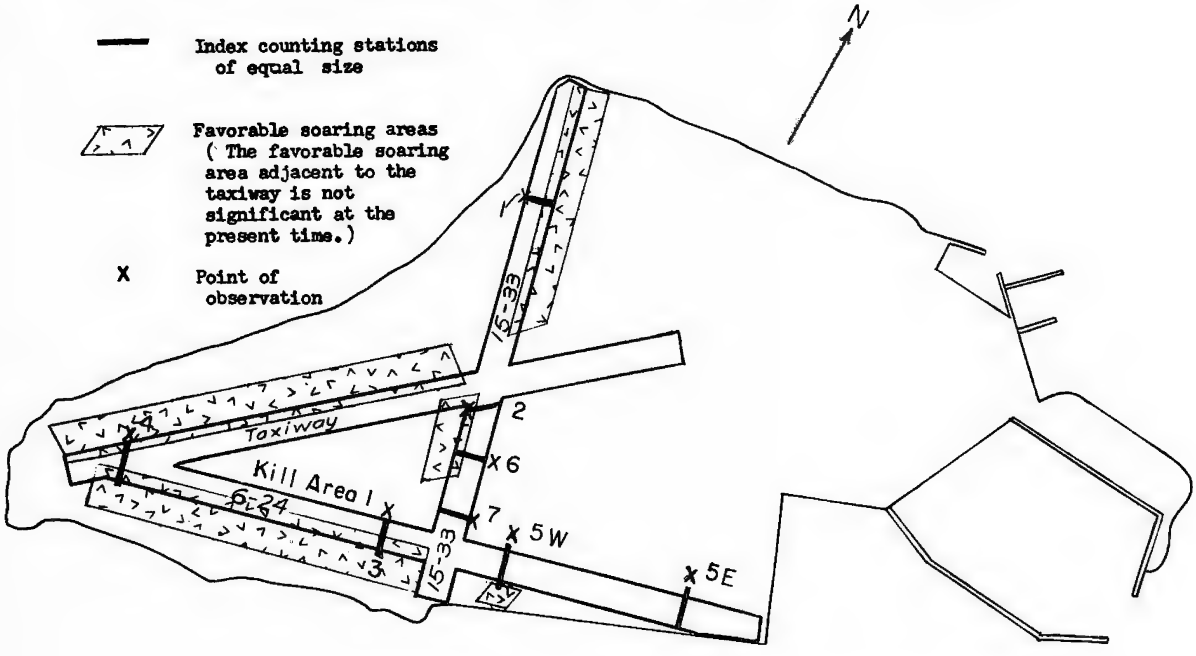


Figure 21. Stations for counting soaring albatrosses on Sand Island, Midway, June 1957.

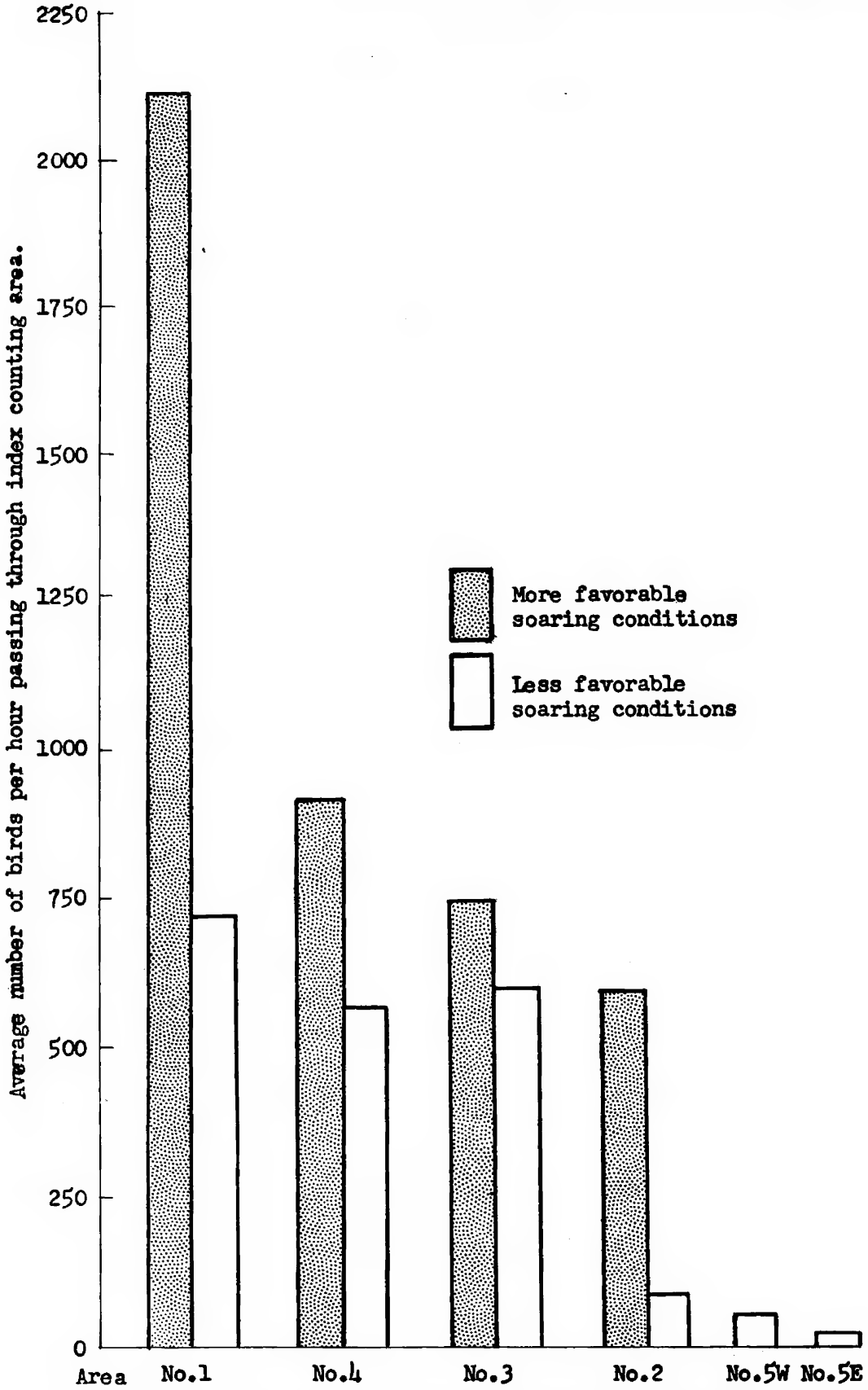


Figure 22. Difference in albatross soaring resulting from wind direction in relation to terrain.

Station 3. Middle of runway 6-24, immediately west of 15-33. Observer on north side. Revetments and medium-height trees on south side, create favorable updrafts.

Station 4. West end of runway 6-24. Observer on north side. Revetments and medium-height trees on south side, create favorable updrafts. Area very similar to area 3.

Station 5W. On eastern half of runway 6-24. Observer on north side. Area level, except for a few small scattered piles of sand and one block house covered by low bushes along south side. These create minor updrafts, but the area is much less favorable to soaring than all areas except 5E.

Station 5E. East end of runway 6-24. Observer on north side. Area absolutely level. No updrafts created.

The average number of birds per hour passing the index points is presented in Figure 22. The decided influence of terrain features on the abundance of soaring birds is obvious. Under certain wind conditions, the number of birds over the area with the highest trees and dunes is 165 times as great as it is over the level area, or expressed in another way the birds are increased by over 16,000 percent where soaring conditions are favorable.

In order to establish with certainty that the updrafts resulting from the presence of dunes and tall vegetation were responsible for increased soaring the figures were broken down and analyzed according to wind direction. Winds blowing across the runway toward the wall of dunes and vegetation would produce the strongest updrafts; these we have termed "more favorable" wind directions. Winds blowing onto the runway from over the top of the obstructions would create poorer soaring conditions; these we have termed "less favorable" winds. Figure 22 illustrates the marked difference in the abundance of birds resulting from different wind directions.

Statistical tests were used to compare counts made at stations 1, 2, 3, and 4 under favorable wind directions with those made at these same stations under unfavorable wind directions. They showed a highly significant difference due to wind direction. In fact, the probability that the difference could have resulted from chance alone is considerably less than one in a thousand.

In order to evaluate the effect of terrain modification, which removed favorable soaring conditions, two counting sectors of equal size were chosen near runway 15-33. During many observations prior to mid-April it was noted that numerous albatrosses soared along the embankment of sand overgrown with Scaevola and ironwood trees that bordered 15-33. A number of these birds turned and banked out over the runway. In late April and early May about one-third of this area was flattened for use in water catchment. Counting station 6 was chosen opposite

the unchanged dune and vegetation area. Station 7 was established about 100 yards distant and faced the newly cleared part (Figure 21). Fifteen runway counts of albatrosses were made in these index sectors under varying wind conditions. The average number of albatrosses per hour at counting station 6 (favorable soaring area) was 515 albatrosses per hour; at station 7 (unfavorable soaring area), 64 albatrosses per hour were counted. Soaring birds were thus 8 times as numerous adjacent to the uncleared runway sector as where the obstructions causing favorable soaring conditions had been removed.

This result occurred even though some birds "spilled over" into the sector covered by station 7 from the sector of counting station 6, because of their proximity to each other. The counts recorded in these two stations, in conjunction with those made in other runway sectors (Figure 21), indicate that the farther the obstructions causing favorable soaring conditions are removed from the runway, the fewer will be the birds which actually wheel out over the runway itself.

Discussion and Recommendations

Methods for Controlling Albatrosses Over Runways

It has been a common experience in wildlife management that habitat control is frequently a more practical method for controlling wild populations than direct action against the individual members of the population in question. As long as the living conditions remain favorable, control of most species through killing is expensive in manpower, the results are slow in being achieved, and the problem usually is not permanently solved. Usually, if constant effort is not exerted the situation will soon again be out of control due to natural increase and spread of the troublesome population.

During our albatross population reduction experiment it became obvious that a "clean sweep" of birds present at any given time eliminated only a part of the total population. It became increasingly apparent that in order to be effective a killing program would have to be systematically carried out during a number of months to eliminate all of the birds occupying the area that particular year. Also it seemed probable that it would have to be continued for an indefinite number of years to take care of the young birds which are seeking nesting sites for the first time. During this period it is probable that the number of birds over the runways would diminish but slowly unless other measures were taken. To date no change is noticeable in the number of birds soaring over the runways that can be considered a result of the limited killing program conducted in 1957. This indicates that to achieve even temporary relief from the bird hazard would require a much more extensive population reduction than was achieved by the killing of about 6000 birds this year.

Observation of albatross while in the air over runways has suggested a method of control which strikes at the core of the difficulty and if successfully carried out would be permanent. It was noted that any topographical feature that causes up-drafts produces

conditions favorable for soaring and large numbers of birds gather in such areas to soar for considerable periods. If these areas are adjacent to runways the birds wheel out over these strips. During our many hours of runway watches we have seen certain birds marked with dye, for individual recognition, soar past repeatedly. Not content to ride only the updrafts, they appear to enjoy skimming out a number of yards over nearby level areas, where, under present conditions they sometimes come in contact with aircraft. Sufficient up-drafts to invite soaring are created by piles of earth, high bushes, and trees along the runways.

On the basis of observations and information now available we believe that the most promising method of permanently reducing the aircraft hazard to albatrosses is to clear and flatten the earth for a distance of 750 feet from the centerline on both sides of the duty runways. If practicable (for water catchment) these areas could be blacktopped. This would give the best assurance of eliminating not only soaring areas, but also breeding and resting areas close to the runways. If black-topping is not feasible a planting program employing low or flat growing grasses or herbaceous species might be tried. This would prevent the blowing of sand over the runways and from piling up into dunes again.

Specifically it is recommended that the entire area within 750 feet from the center and on each side of Runway 6-24, which is now the main duty runway, be flattened as soon as possible. About two-thirds of this area has already been flattened in connection with construction work so it would merely be continuing an operation which has already been started. If this proves successful in obtaining control of the albatross hazard to aircraft over Runway 6-24, the same process, modified if experience so dictates, could be extended to Runway 15-33 when it again becomes functional.

Protection of the Black-footed Albatrosses

It is apparent that the black-footed albatross constitutes an insignificant fraction of the birds killed on runways. For this reason, far less time has been devoted to studies of this bird than to the tenfold more abundant Laysan albatross.

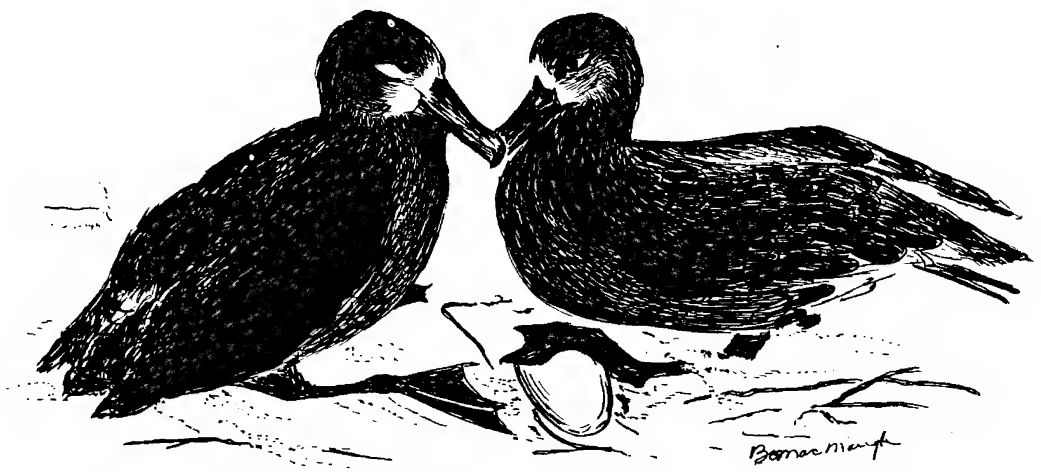
Judging from population estimates of this year as compared with those for 1945 made by Fisher and Baldwin*, it appears that the population of black-footed albatrosses on Sand and Eastern Islands has decreased from 69,000 to 16,000. We estimate that construction alone wiped out at least 20 percent of the 3659 Sand Island nestlings during the spring of 1957.

* Fisher, Harvey I., and Paul H. Baldwin
1946 War and the birds of Midway Atoll.
The Condor 48:3-15

It has been a general observation, as yet not confirmed or analyzed by quantitative studies, that the number of unemployed black-foots is proportionally less than that of Laysans. It also appears that the unemployed black-foots desert the breeding grounds sooner than the Laysans.

At all times it was noted that practically all bird strikes by planes were of the Laysan albatross. This is undoubtedly, in part, a reflection of the relative number of the two species on the island. There is indication from our counts, however, that strikes involving black-footed albatrosses are much less than would be expected from known proportions of the two species in the air over the runways and may indicate that the black-footed species is more adept at getting out of the way of aircraft. The affinity of black-foots for shoreline areas is probably also a contributing factor.

For the above reasons we consider that the black-footed albatrosses should be spared from any future killing program.



PART II. SOOTY TERN STUDIES

Populations

During the first week of March a few sooty terns began to circle in the evenings over the southeastern portion of Sand Island and over Runway 6-24. By March 15, the flock had increased to several thousand birds, and they began to rest on the ground during the night. After that there was a gradual increase in numbers, and they soon began to settle on the ground during the daytime.

The first egg was laid on May 11. Following that, laying progressed rapidly. On May 30, we conducted a census of the sooty tern population on Sand Island. There were three distinct colonies occupying a total area of 420,000 square feet. Counts on ten randomly selected sample plots, each 10x10 feet, indicated an average of 11.6 eggs per plot. From this a total of 48,720 eggs was calculated. The nesting population, allowing two adults for each egg, was therefore 97,440. Adding an estimated 50 percent for birds in the air which had not yet established nests, a calculated total of approximately 150,000 sooty terns was present on the island at that date. After that an undetermined number of additional birds arrived at the island.

Control Experiments

Since the sooty terns are expected to be a problem in the event that jet aircraft use Midway, control experiments were conducted.

Harassment Program

As a result of discussions with Dr. Martin Moynihan of Harvard University, who has made intensive studies of the behavior of gulls and terns and who was visiting Midway at the time, it was decided to instigate a harassment program directed toward driving the sooty terns away from their nesting grounds. This program was begun with the cooperation of the Navy on March 19. Considerable material and manpower were invested by the Navy in this experiment which was terminated on May 11. A total of 65 man-days (exclusive of time put in by the Marine Guard, the biologists, and Lt. Picht) were used on this project. A total of 2238 gallons of diesel oil was burned, and 890 aircraft distress signals, 107 aircraft float lights, 750 12-gauge shotgun tracer sheels, and 2025 12-gauge shotgun 00 buckshot were used. Procedure was as follows:

March 19 to April 12. Once during each patrol, at approximately hourly intervals, the Marine guards stopped at the area where the sooty terns were settling on the ground and fired red and green flares into the flocks. After about two weeks the flare supply was depleted and smoke flarelights were burned on the ground. The terns were not kept off the ground entirely during this period, but they were considerably upset.

April 12 to April 15. Two men were assigned to harass the terns constantly during the night. Since the visits of the Marine patrol did not have the effect of keeping the terns constantly off the ground, the two men assigned were given shotguns with tracer ammunition. The birds were kept off the ground from sunset to sunrise. At dawn most of the birds had left the area, but each day the flock began to grow progressively larger during mid-morning, and by April 15 some were landing in the afternoon.

April 15 to April 22. The watch was changed so that one man came on duty at 2 p.m. The second man finished his duty at 2 a.m. On April 16, two oil drums were cut in half and placed on the tern's landing area. Each half drum was filled with diesel oil and kept burning during the entire night. This method, along with shooting, is very effective in keeping the terns in the air.

April 22 to May 11. The biologists turned the project over to the Navy, because too much time was being consumed hauling oil to the oil burners, and the management of the men was handled by a naval officer.

The experiment was successful in driving the sooty terns away from their ancestral nesting area on Sand Island. The sooty terns were unable to land and establish their nesting territories on the area they desired until the experiment was discontinued. However, the experiment was not successful in driving the terns away from Sand Island to areas such as Eastern Island, where they would not constitute a potential problem to aircraft. When the frustrated terns were unable to land on the area they desired most, they moved to other areas adjacent to Runway 6-24 and began to lay their eggs almost immediately. The first eggs were found in two other areas on May 10 and 11. The harassment program was, therefore, discontinued on May 11. Immediately vast numbers of terns settled on the harassment area.

It was concluded that in view of the vast numbers of sooty terns now present at Sand Island, and the considerable amount of manpower and material expended with negative results, it would be impractical to attempt to eliminate the sooty terns from the air over the runways through this type of program. We believe the persistent effort put forth by the Navy on Midway conclusively demonstrates that, within the limits of practicality, sooty terns cannot be driven from their ancestral nesting grounds by these methods.

Habitat Control

Sooty terns are most attracted to open sandy areas. However, their instinct to return to areas long used by a particular group is apparently so strong that they will land and nest successfully on areas that become covered with considerable plant growth. We understand that this has been the case in certain areas on Sand Island.

An approach to the problem would be to find what types of habitat modification will most effectively discourage the nesting of

these birds. In order to establish their nesting territories on the ground the sooty terns apparently require open areas between trees and shrubs or other obstructions plus a natural earth surface. This knowledge suggests two possible methods.

Wire mesh ground cover.--A strip of galvanized wire mesh was placed over the ground where sooty terns were landing in March 1957. Where the wire mesh was held firmly above the ground the birds were repelled. Where the wire sagged and touched the ground, the birds landed. Although wire mesh could be used to prevent successful nesting, we believe that, in view of the large areas that would have to be covered, the expense of the material, and the considerable labor involved in installation and maintenance, this control measure is impractical.

Black-top surfacing.--It has been demonstrated on Sand Island that sooty terns do not nest on hard-surfaced areas. In view of this knowledge it is possible that the current extensive program of surfacing for water catchment in areas adjacent to Runway 6-24, will exclude sooty terns from areas where they nest at present and constitute a potential problem to aircraft. Advantage will be taken of this opportunity to make observation which should give the answer as to the effectiveness of this type of habitat modification. Hard surfacing of the ground for a sufficient distance on both sides of operational runways might keep the nesting birds far enough away so that they would not be a hazard. It is not known what this distance would have to be, however, but it is certain that it would be very costly and probably not feasible unless combined with some other purpose such as water catchment.

Poisoning

Two experiments were conducted to test the effectiveness of TEPP (tetraethyl pyrophosphate), a strong contact poison affecting the nervous system, in eliminating sooty terns. Captain O. M. Trier of the U. S. Army Chemical Corps cooperated in these experiments and supervised the handling and application of the poison.

Experiment 1.--On June 4 at 7 a.m., shortly after sunrise, all sooty terns and their eggs in an area 50x50 feet, in the center of Zone 5, were sprayed with a 3 percent stock solution of TEPP-40 in water. A small amount of a chemically inert wetting agent, E51-c-1063-165, was added. The area sprayed contained approximately 290 eggs and 580 sooty terns.

Care was taken to saturate the plumage of many birds, and all those which remained on the ground (estimated at more than 50 percent) were sprayed about the eyes and into the open mouths from a range of a few inches. All eggs were saturated with the spray. All birds returned and settled on their eggs within 3 to 5 minutes.

Results: Several birds appeared dazed or "dopey." The area was inspected at two-hour intervals through the day. Not one bird was known to be killed by the TEPP.

Experiment 2.--At 8 p.m., about one-half hour before sunset, a second spraying operation was conducted. This was conducted as outlined under experimental, except that a 6 percent solution of TEPP-40 was used, and no wetting agent was added.

Results: Twelve birds were killed (about 4 percent of those hit directly with spray). All of these died within 15 minutes of contact with the poison spray. The area was inspected at daybreak, and twice later in the day. No indication of additional mortality was found. The birds carried on their usual activities as though nothing had happened.

Discussion.--A 6 percent stock solution of TEPP-40 is the strongest that could be used within the limits of practicality. The increased danger to personnel, including the many construction workers present on the island, would prohibit the use of a more concentrated solution. Possibly sooty terns are more resistant to this poison than other animals. Captain Trier and the biologists decided that the two tests conducted were sufficient to indicate a conclusion.

Conclusion.--Because of the unavilability of the proper wetting agent (propylene glycol) it is impossible to say whether or not the kill from the tests made was the maximum possible with TEPP-40. However, because TEPP is completely miscible with water and many birds were sprayed in the eyes and open mouth, it appears probable that the two tests constitute a good indication of the ability of this poison at safe concentration levels, to control sooty terns. Our conclusion from this experiment is that TEPP-40 is not a practical agent for the reduction of sooty terns on Midway under present conditions of the human population.

Sooty Terns and Aircraft Operations

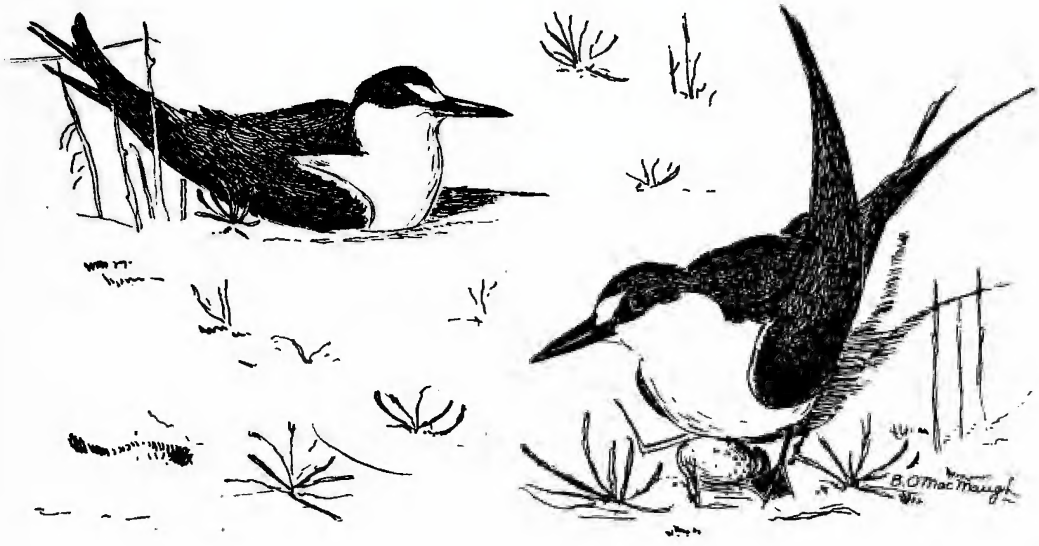
Frequency of Sooty Tern Strikes

Runway 6-24 was opened for use on June 1, 1957. The eastern end of this runway passes between the sooty tern colony and the sea. Sooty terns fly over this runway on their way to and from their nesting territories.

During the period from June 1 to June 15, a total of 99 dead sooty terns were found on Runway 6-24. These were collected daily by the Fire Department pick-up crew. During this period there were a total of 86 aircraft landings plus take-offs. This is an average of 1.15 birds killed per landing or take-off. This is a maximum figure because some of these may have been killed by trucks.

Damage Resulting from Sooty Tern Strikes

During the period of our study, there was no record of any damage to aircraft resulting from sooty tern strikes.



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